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PLANT PHYSIOLOGY.—*Physiological effects of certain fungitoxic compounds on fungus cells.*[1] HUGH D. SISLER AND NORTON L. MARSHALL,[2] Department of Botany, University of Maryland. (Communicated by Carroll E. Cox.)

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There has been considerable interest in the physiological effects of fungicides on fungus cells. The ultimate aim of work of this kind is to establish the site and nature of the reaction between the fungicide and the components of the fungus cell which accounts for the inhibition of cell growth. While certain inhibitors probably affect a specific reaction in the cell, others undoubtedly have a more generalized effect, inactivating a certain type of chemical group in any phase of metabolism in which such groups may occur. The interaction of certain fungicides with different types of enzymes was studied by Owens (1953). In order to localize the principal site or sites of action of inhibitors, it is desirable to know which general phase of metabolism of the cell is affected by the compounds under study. A knowledge of the general effects of various inhibitors on fungus cells should also indicate whether these compounds act in similar or different manners in inhibiting cell growth.

The present study was conducted with the purpose of determining which general area of metabolism of fungus cells is affected by certain types of fungitoxic chemicals. The inhibitors were ziram (zinc dimethyldithiocarbamate),[3] sulfanilamide, sodium azide, and the antibiotic cycloheximide (Acti-dione).[4]

MATERIALS AND METHODS

Conidia of *Fusarium roseum* Lk. were grown on modified Tochinai's medium and prepared for manometric studies by the method described by Sisler and Cox (1954). The medium for subsequent growth and manometric studies was composed of glucose, 20 g; $(NH_4)_2SO_4$, 2 g; KH_2PO_4, 5.4 g; K_2HPO_4, 2.5 g; $MgSO_4 \cdot 7H_2O$, 0.5 g; distilled water to make 1,000 ml; pH 6.4.[5] The inorganic components of this medium excluding the ammonium sulfate will be referred to as the basal medium. In the manometric studies, conidial suspensions were prepared in the basal medium and 1 ml of a standardized suspension containing 1 mg dry weight of conidia was added to each vessel. Glucose or glucose and $(NH_4)_2SO_4$ were added from the sidearms of the vessels at the initiation of an experiment. The final liquid volume per vessel excluding the KOH solution was 2 ml. In order to increase the accuracy of the dry weight determinations, growth experiments were conducted with 16 ml aliquots of conidial suspensions shaken in 50 ml erlenmeyer flasks. These flasks were open to the atmosphere (cotton plugged) and did not contain KOH, but other-

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[2] Part of the data concerning ziram presented in this paper was contained in a thesis submitted by the junior author to the Faculty of the Graduate School of the University of Maryland, May 1955, in partial fulfillment of the requirements for the degree of doctor of philosophy.

[3] Prepared from the sodium salt which was supplied through the courtesy of E. I. du Pont de Nemours & Co., Inc., Wilmington, Del.

[4] Reagent grade Acti-dione was furnished through the courtesy of the Upjohn Co., Kalamazoo, Mich.

[5] This medium will support germination and some subsequent mycelial growth of conidia of *F. roseum* harvested from the modified Tochinai's medium. It has recently been determined, however, that biotin is required for maximum growth.

wise the conditions were identical with those used in the manometric experiments.

Cells of *Saccharomyces pastorianus* Hansen were grown in a medium composed of: glucose, 20 g; $(NH_4)_2SO_4$, 3 g; KH_2PO_4, 3 g; $MgSO_4 \cdot 7H_2O$, 0.25 g; $CaCl_2$, 0.25 g; glycine, 1 g; thiamine HCl, 200 μg; biotin, 10 μg; niacin, 200 μg; inositol, 2 mg; pyridoxine HCl, 100 μg; folic acid 100 μg; and the trace element supplement of Burkholder (1943); distilled water 1,000 ml; pH 4.7. This medium was used in studies with cycloheximide. In studies with ziram the medium in which yeast cells were grown and which also was used in the respirometer did not contain the trace element supplement and included 1 g of sodium acetate per liter in addition to the other components listed for the medium used in cycloheximide studies. The pH of this medium was 5.4. In manometric studies, suspensions of yeasts were prepared in a solution from which the glucose, glycine, ammonium sulfate, and sodium acetate were omitted and these components were added from the sidearms of the vessels when desired. The quantity of yeast used was 0.5 mg dry weight per vessel in experiments with ziram and 0.3 mg per vessel in experiments with cycloheximide. Suspensions of ziram were prepared by the method described by Sisler and Cox (1954) for making suspensions of thiram. All growth and manometric studies were conducted at 30°C.

For organic acid determinations, mycelium of *F. roseum* was grown in a solution of $MgSO_4 \cdot 7H_2O$ 0.5 g; KH_2PO_4, 0.5 g; peptone, 5 g; glucose, 2.5 g; distilled water, 1,000 ml. The medium was inoculated heavily with conidia and hyphal fragments and the culture shaken for 18 hours at room temperature. The mycelium was collected, washed twice with distilled water, and pressed. This fungus cake weighing approximately 25 g, was divided in half and each portion was suspended in 500 ml of basal medium with 0.01 M glucose or 0.02 M pyruvate as a source of carbon. The cultures were shaken for a period of three hours at room temperature. Ziram was then added to one of the cultures to give a final concentration of 153 p.p.m. The cultures were shaken for an additional hour at which time the mycelium was collected, washed and pressed as previously described.

The fungus cakes were each placed in 50 ml of ether plus 1 ml of 1N H_2SO_4 in ether, stirred thoroughly and stored overnight at 4°C. The fungus material and ether were then transferred to a soxhlet apparatus and the extraction carried on for 5 hours. The extracts were evaporated and the residues were taken up in 1 ml of acetone.

Fifty μl of this acetone solution was spotted on Whatman no. 1 filter paper in 5-microliter aliquots. The chromatograms were developed in the first dimension with a solvent mixture of 70 parts by volume n-butanol, 1 part formic acid and sufficient water to saturate. The second dimension solvent mixture was 70 parts by volume isobutanol, 15 parts formic acid, and 15 parts water. Upon completion of the development, the papers were hung in a ventilated cabinet until freed of the swamping acid and then sprayed with a pH 7.3 indicator solution of 0.04 percent bromcresol green in ethanol.

The organic acid components of the extracts were tentatively identified by comparing their R_f values with those of known acids. However, since the presence of contaminating materials in the extract may influence R_f values, the identification of each component was confirmed by chromatographing a sample of extract to which a known acid was added. If upon development, the reinforced extract still separated into the same number of components, one of which was enlarged, the identity of the acid was assumed to be established.

Since the alpha-keto acids are relatively unstable, they were extracted and chromatographed as hydrazones. The mycelium of *F. roseum*, prepared as previously described for ether extraction, was placed in 50 ml of a 0.75 per cent solution of 2, 4-dinitrophenylhydrazine in 5N H_2SO_4, stirred thoroughly for 1 hour at room temperature and allowed to stand over-night at 4°C. Fifty ml of ethyl acetate was then added, the mixture stirred and filtered through Whatman no. 41H filter paper. The fungus material was extracted with four 25 ml portions of ethyl acetate and filtered. All filtrates were combined and the two phases separated. The aqueous fraction was washed with 20 ml of ethyl acetate and discarded. The hydrazones were then purified by the procedure described by Cavallini, Frontali, and Toschi (1949).

The purified hydrazones were applied to Whatman no. 4 paper in a solution of 2 parts ethanol, plus 3 parts 0.05 M phosphate buffer, pH 7.2. The chromatograms were developed with a solvent mixture consisting of 70 parts by volume

isobutanol, 15 parts water, 10 parts ethanol, and 1 part concentrated NH_4OH. The spots were identified by comparing their R_f values with those of known acids and by reinforcement of the extract as previously described.

When it was desired to have a more accurate quantitative comparison than could be achieved simply by inspection, the hydrazones were eluted and the quantities determined by the method of Cavallini, Frontali, and Toschi (1949).

RESULTS AND DISCUSSION

Fusarium roseum was the organism used most extensively in studies of the effects of inhibitors on growth and oxygen uptake. The increase in dry weight and the rate of oxygen uptake of "resting"[6] and growing conidia of this fungus during a 5-hour period in the absence of any inhibitor is illustrated in Fig. 1. The rapid increase in dry weight of both resting and growing conidia during the first hour is attributed largely to the accumulation of inorganic salts and glucose. At the end of 1 hour the dry weight and the rate of oxygen uptake of resting conidia are essentially identical with those of growing conidia. Thereafter, the rate of oxygen uptake and dry weight of conidia furnished with a source of nitrogen expand rapidly. This is the pattern which would be expected for growing cells. The rate of oxygen uptake of resting conidia remained essentially constant at the level reached during the first hour, whereas their dry weight increased steadily during the entire course of the experiments. The bulk of the dry weight increase of resting conidia after the first hour probably results from the accumulation of fat. Accumulation of fat by these cells under conditions of nitrogen starvation has been reported (Sisler and Cox, 1954).

The respiratory quotient as determined by the direct method (Umbreit, Burris, and Stauffer, 1949) for resting conidia was 1.11 for the first hour and 1.25–1.35 during the following 4-hour period; for growing conidia it was 1.06 for the first hour and 1.13–1.16 during the following 4 hours.

Ziram.—A concentration of ziram (15 p.p.m.) sufficient to prevent growth of conidia of *F. roseum* also inhibited the respiration of resting

[6] The term resting conidia is used to designate those conidia in basal medium plus glucose (minus nitrogen medium) and the term growing conidia is used to designate conidia in basal medium plus glucose and $(NH_4)_2SO_4$ (complete medium).

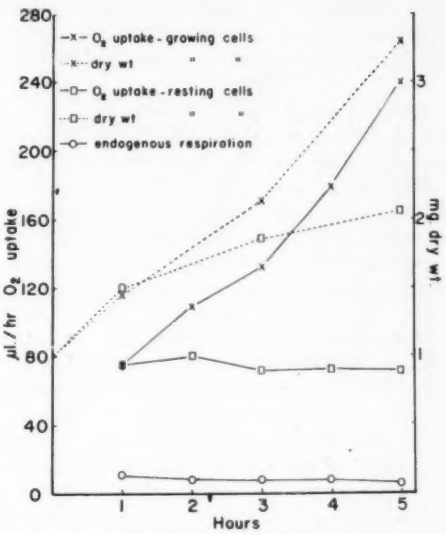


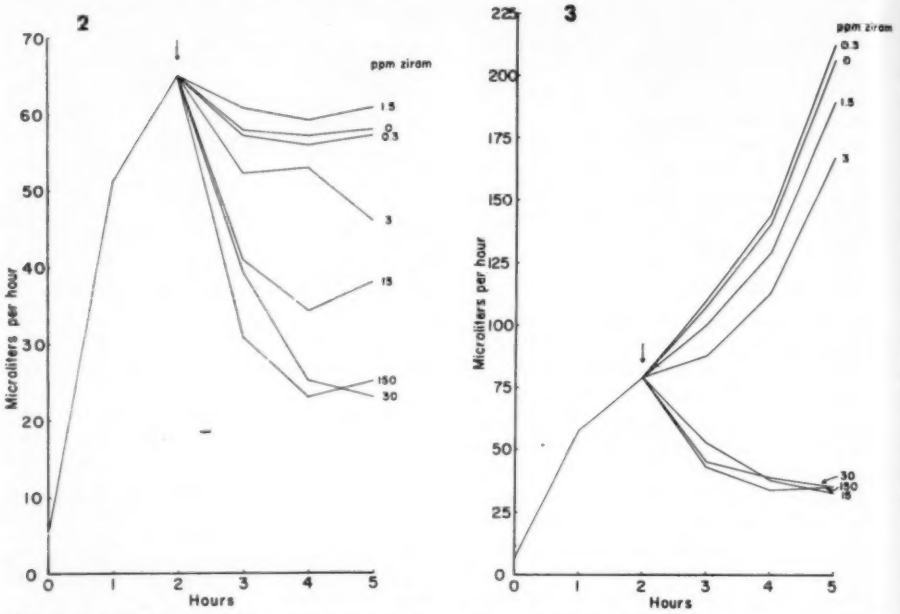
FIG. 1.—The rate of oxygen uptake and dry-weight changes of resting and growing conidia of *Fusarium roseum*.

conidia (Figs. 2 and 3). Inhibition in the rate of glucose oxidation of the resting conidia was approximately 40 percent. Increasing the concentration of ziram to 30 p.p.m. resulted in somewhat greater inhibition of oxygen uptake but no further inhibition occurred with ziram at 150 p.p.m. Concentrations of ziram greater than 15 p.p.m. (i.e., 30 and 150 p.p.m.) did not increase the degree of inhibition of oxygen uptake beyond that obtained by 15 p.p.m. in the case of growing conidia.

Anaerobic fermentation of glucose and the oxidation of pyruvate by conidia of *F. roseum* were of the same order of sensitivity to ziram as the oxidation of glucose.

In the case of *S. pastorianus*, concentrations of ziram up to 40 p.p.m. affected only that portion of respiration associated with new growth. The respiration already established at the time ziram was added was not depressed as it was in the case of *F. roseum* (Fig. 4).

Klöpping (1951) reported that respiration of the mycelium of *Penicillium italicum* and *Aspergillus niger* is less sensitive than spore germination to sodium dimethyldithiocarbamate (NaDDC). However, it would be necessary to compare the effect of this fungicide on the respira-



FIGS. 2, 3.—The effect of various concentrations of ziram on the rate of oxygen consumption by resting and growing conidia of *Fusarium roseum*. Ziram was added at the time indicated by the arrow. Fig. 2: Resting conidia, Fig. 3: Growing conidia.

tion and germination of spores of these fungi to determine whether respiration of the spores is affected at minimum growth-inhibiting concentrations. Goksøyr (1955) found that the oxidation of glucose by cells of *S. cereviseae* is less sensitive than growth to dithiocarbamyl compounds, and McCallan, Miller, and Weed (1954) found lower ED_{50} values for ferbam[7] for germination of spores of *Neurospora sitophila*, *Alternaria oleraceae*, and *A. niger* than for oxygen uptake, whereas a higher ED_{50} value for spore germination than for oxygen uptake was obtained for *Monilinia fructicola*.

Thus it would appear that the species of fungus used as a test organism may be an important factor in determining whether a growth-inhibiting concentration of a dithiocarbamyl compound will also inhibit respiration.

The inhibition of respiration of *F. roseum* by ziram may not result from a direct effect of this compound on enzymes involved in the oxidation of glucose. The fact that an increase in ziram beyond a certain concentration did not give a corresponding increase in inhibition of glucose oxidation would support this view. If the rate of glucose oxidation were limited by the rate of utilization of the ATP thus produced, then any

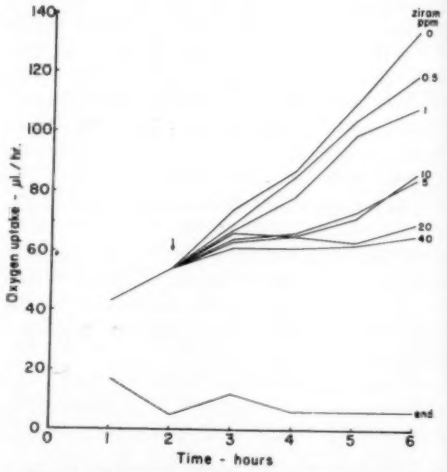


FIG. 4.—The effect of various concentrations of ziram on the rate of oxygen consumption by growing cells of *Saccharomyces pastorianus*. Ziram was added at the time indicated by the arrow; end. = endogenous respiration.

[7] Ferric dimethyldithiocarbamate.

inhibition of synthetic reactions utilizing ATP, would probably be reflected as an inhibition in the rate of glucose oxidation. This type of effect would account for the pattern of respiratory inhibition obtained when conidia of *F. roseum* are treated with ziram. If the rate of glucose oxidation were not normally limited by the rate of cycling of ATP or if alternate energy utilizing reactions or ATPase were available to remove ATP, growth might be inhibited without a depression in the rate of oxygen uptake. This may be the case with *S. pastorianus* where the oxygen uptake is not depressed by ziram at growth-inhibiting concentrations.

A study of organic acid metabolism in *F. roseum* was made for the purpose of elucidating the nature of the effect of ziram on the oxidation of glucose and pyruvate. Chromatographs of ether extracts from the mycelium of *F. roseum* incubated with pyruvate or glucose showed spots corresponding in R_f values to citric, malic, alpha-ketoglutaric, succinic, and fumaric acids. The principal consistent difference between the extracts from untreated cells and cells treated with ziram was an excess of alpha ketoglutaric acid in the ziram-treated samples (Figs. 5, 6). Citric acid was usually deficient in the ziram-treated samples in comparison with that found in untreated samples. Pyruvic acid was apparently destroyed by the extracting procedure. However, by extracting the keto-acids as hydrazones, the presence of pyruvic as well as alpha-ketoglutaric acid could be demonstrated when either glucose or pyruvate was used as substrate. When sufficiently large samples of the extracts were chromatographed, small spots corresponding in R_f value to oxaloacetic acid could also be detected. There was two to 10 times as much alpha-ketoglutaric acid in extracts from ziram-treated samples as in untreated samples. Visual inspection of the chromatograms indicated that pyruvic acid in extracts from ziram-treated mycelium was only slightly in excess of that in the untreated mycelium.

Sijpesteyn and van der Kerk (1954) have shown that several alpha-keto acids are antagonistic to the fungitoxicity of NaDDC. The same authors (1956) have reported the accumulation of pyruvic acid in the medium in cultures of *A. niger* and *P. italicum* treated with NaDDC. The accumulated pyruvate apparently plays a role in offsetting the toxic effect of the fungicide in the case of *A. niger* but not in the case of *P. italicum*. They suggested that the accumulation of pyruvic acid may result from an inhibition of pyruvate oxidase.

The mechanism by which ziram induces accumulation of alpha-ketoglutaric acid in the mycelium of *F. roseum* has not been established. Interference with —SH groups of the alpha-ketoglutaric-oxidase system may be responsible for the accumulation of this acid. This type of inhibition might be expected to cause a reduction in the rate of respiration as was observed when conidia of *F. roseum* were treated with ziram. Sijpesteyn and van der Kerk (1956) have suggested the possible interference of NaDDC with alpha-lipoic acid or coenzyme A which are —SH components of the pyruvate oxidase system. These —SH compounds also function in the alpha-ketoglutaric oxidase system. Goksøyr (1955) has suggested the possibility of competition of dithiocarbamyl compounds with coenzyme A for proteins of the cell.

An alternative explanation for the accumulation of keto acids and one which is consistent with the view that dithiocarbamyl compounds do not affect or only indirect affect the systems involved in the oxidation of glucose is that the accumulation represents that fraction of these acids that would normally be utilized in amino acid and other syntheses. If synthesis were stopped while the oxidation of glucose and the formation and oxidation of alpha-keto acids continued uninhibited or only partially inhibited, then the keto acids normally utilized in synthesis would in all probability accumulate.

Sulfanilamide.—Sulfanilamide has no effect on the respiration of most microorganisms (Tatum and Giese, 1945). These authors found that oxidation of sucrose by resting conidia of *Neurospora* was unaffected even by saturated solutions of this compound, whereas spore germination was completely inhibited at much lower concentrations. Mycelial growth of *Neurospora* was considerably more resistant to sulfanilamide than was spore germination.

Sulfanilamide was the only inhibitor in the present studies which clearly did not inhibit glucose oxidation or dry weight increase of resting conidia of *F. roseum* at concentrations which inhibited growth and the increase in oxygen consumption associated with growth (Table 1). The actual inhibition of growth and the associated

oxygen consumption is probably much greater than is indicated by the values for growing cells in Table 1, since a portion of the oxygen consumption and of the dry weight increase of growing cells probably corresponds to the sulfanilamide resistant fractions which occur in resting cells. When corrections are made by subtracting the values for oxygen consumption and dry weight increase of resting conidia from the corresponding values for similarly treated growing conidia, an inhibition of 82 percent for the remaining oxygen consumption and 87 percent for the remaining dry weight increase are obtained when sulfanilamide is 10^{-3} M.

TABLE 1.—EFFECT OF SULFANILAMIDE ON THE DRY-WEIGHT INCREASE AND ON THE OXYGEN CONSUMPTION OF GROWING AND RESTING CONIDIA OF FUSARIUM ROSEUM.[1]

	Molar concentration of sulfanilamide	Oxygen consumed-microliters/mg initial dry weight	Dry-weight[2] increase/mg initial inoculum	Percent inhibition of oxygen consumption	Percent inhibition of dry weight increase
Growing conidia	0	849	2.27	—	—
	10^{-5}	835	2.21	1.7	2.7
	10^{-3}	633	1.83	25.4	19.4
	10^{-2}	480	1.27	43.5	44.0
Resting conidia	0	402	0.84	—	—
	10^{-5}	401	0.86	0.3	+2.4
	10^{-4}	402	0.90	0.0	+7.1
	10^{-3}	399	0.90	0.8	+7.1

[1] All values are from five hour experiments.
[2] Values for dry-weight increase were obtained by determining the final dry weight and correcting for the dry weight of the initial inoculum.

The effects of sulfanilamide appear to be restricted to processes involved in the synthesis of nitrogenous compounds. Synthetic processes characteristic of resting cells such as fat synthesis are apparently unaffected by this compound.

Cycloheximide.—Whiffen (1948, 1950) found that cycloheximide is toxic to most phytopathogenic fungi and to certain yeasts but not to bacteria. *S. pastorianus* is very sensitive to cycloheximide and is generally used as an organism for the assay of this antibiotic.

Lower ED_{50} values for cycloheximide were reported by McCallan, Miller, and Weed (1954) for spore germination than for oxygen uptake in the case of spores of *Neurospora sitophila*, *Myrothecium verrucaria*, *Alternaria oleraceae*, and *Aspergillus niger*. A lower ED_{50} value for oxygen uptake than for spore germination was found for spores of *Monilina fructicola*. Under somewhat different conditions Walker and Smith (1952) found that the respiration of spores of *Myrothecium verrucaria* is 4 times as sensitive to cycloheximide as is spore germination and 10 times as sensitive to this compound as is mycelial respiration. Approximately ten percent of the respiration of the spores was considered necessary for growth.

The effect of this compound on the oxygen uptake of resting and growing conidia of *F. roseum* and on cells of *S. pastorianus* is similiar to the effect of ziram on the oxygen uptake of conidia of *F. roseum* (Tables 2 and 3). While it appears that growth and the oxygen uptake associated with growth may be somewhat more sensitive to cycloheximide than the respiration of resting cells, the latter is affected by concentrations which prevent growth. As is the case with ziram, the respiration of resting cells of *F. roseum* is depressed about 50 percent by concentrations which prevent growth. It should be noted that increasing the concentration of cycloheximide beyond 10^{-5} M does not appreciably increase the degree of inhibition of the respiration of resting conidia of *F.*

FIGS. 5, 6.—Two dimensional chromatograms of organic acids extracted from the mycelium of *Fusarium roseum*. The mycelium was incubated with 0.02 M pyruvate. Fig. 5: Organic acids from untreated mycelium. Fig. 6: Organic acids from ziram treated mycelium. From left to right for either figure the spots correspond to citric, malic, alpha-ketoglutaric, succinic, and fumaric acids.

TABLE 2.—EFFECT OF CYCLOHEXIMIDE ON THE RESPIRATION AND GROWTH OF CONIDIA OF FUSARIUM ROSEUM[1]

Molar concentration of cycloheximide	Resting conidia		Growing conidia			
	O_2 consumed/mg initial dry weight (microliters)	Percent inhibition	O_2 consumed/mg initial dry weight (microliters)	Percent inhibition	Dry-weight increase/mg initial dry weight	Percent inhibition
0	336	—	710	—	2.2	—
10^{-8}	335	0	677	5	2.1	5
10^{-7}	317	6	590	17	1.8	18
10^{-6}	250	26	303	57	1.1	50
10^{-5}	175	48	170	76	0.4	82
10^{-4}	168	50				
10^{-3}	160	52				

[1] All values are from 5-hour experiments.

roseum. Anaerobic CO_2 production by cells of *S. pastorianus* in the presence or absence of a source of nitrogen is approximately as sensitive to cycloheximide as is oxygen uptake by these cells (Table 3).

Cycloheximide apparently has some direct effect on carbohydrate oxidation or affects segments of metabolism which are associated closely enough with carbohydrate oxidation to cause some inhibition of the latter process.

Sodium azide.—Following an initial period of inhibition, azide induced a stimulation in the rate of oxidation of glucose by resting conidia of *F. roseum*. This was true for 10^{-3}, 10^{-4}, and 10^{-5} M concentrations of azide. The weight increase of "growing conidia" treated with azide was much less than that for untreated resting conidia even though the oxygen consumed by the former conidia exceeded that of the latter. The oxygen consumption of "growing conidia" treated with azide was almost identical with that of resting cells treated with this compound (Fig. 7).

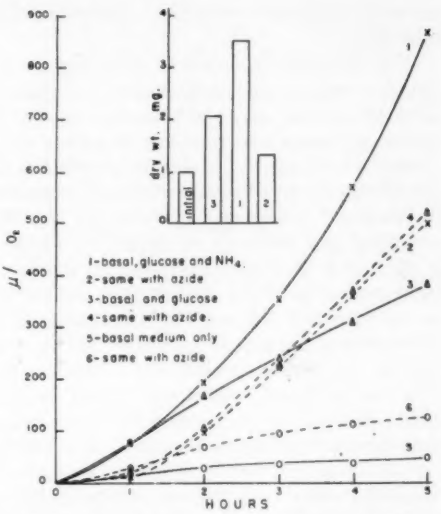


FIG. 7.—Effect of 5×10^{-4} M sodium azide on the oxygen uptake and dry weight increase of conidia of *Fusarium roseum*.

At appropriate concentrations, azide is reported to interfere with energy utilization and assimilation in certain organisms (Clifton, 1946; Spiegelman, 1947; and James, 1953). Complete oxidation of acetate by yeast was obtained in the presence of low concentrations of azide while 66 percent oxidation was obtained with untreated cells (Winzler, 1940). Using washed cells of *E. coli*, Clifton (1938) found that azide-treated cells utilized sufficient oxygen to account for 100 percent oxidation of the added glucose, while untreated cells utilized approximately 50 percent of

TABLE 3.—EFFECT OF CYCLOHEXIMIDE ON THE RESPIRATION, FERMENTATION, AND GROWTH OF CELLS OF SACCHAROMYCES PASTORIANUS[1]

Molar concentration of cycloheximide	Resting cells				Growing cells					
	O_2 consumed (microliters/300 minutes)	Percent inhibition	CO_2[2] produced (microliters/120 minutes)	Percent inhibition	O_2 consumed (microliters/300 minutes)	Percent inhibition	Increase in optical density	Percent inhibition	CO_2 produced (microliters/120 minutes)	Percent inhibition
0	162	—	264	—	235	—	0.43	—	407	—
3.6×10^{-8}	162	0	262	1	217	8	0.38	12	408	0
3.6×10^{-7}	138	15	234	11	145	38	0.10	77	306	25
3.6×10^{-6}	104	36	174	34	101	57	0.06	86	181	56

[1] Initial inoculum in all experiments had an optical density of 0.41 and a dry weight of 0.3 mg.
[2] CO_2 measurements were made in an atmosphere of N_2.

the oxygen required for complete oxidation of the substrate.

With the substrate limited to an amount which would be consumed during the course of an experiment, the oxygen consumed by resting conidia of *F. roseum* treated with 5×10^{-4} M azide would account for 85 percent of complete oxidation of the added glucose, whereas the oxygen consumed by untreated conidia would account for only 20 percent of that necessary for complete oxidation of the added substrate (Table 4). Apparently a large percentage of the carbon from glucose is incorporated into cell material in untreated cells while most of the glucose is oxidized to CO_2 and H_2O by the conidia treated with azide. In calculating the oxygen utilization induced by the added glucose, the assumption has been made that the rate of endogenous respiration of resting cells oxidizing glucose is the same as that of similarly treated cells without substrate. However, assuming that the endogenous respiration is suppressed by the exogenous glucose, the oxygen consumed by azide-treated conidia may approach 100 per cent of that required for complete oxidation of the added substrate.

Azide affects respiration and growth of *F. roseum* in a manner which is generally considered to be characteristic of compounds which interfere with energy utilization by cells.

TABLE 4.—EFFECT OF SODIUM AZIDE ON THE OXIDATION OF GLUCOSE BY RESTING CONIDIA OF FUSARIUM ROSEUM

Medium	Total oxygen consumed (microliters)[1]	Total oxygen consumed minus endogenous	Percent of glucose completely oxidized, based on O_2 consumed[2]
Basal plus 0.5 mg glucose	109	76	20
Basal plus 0.5 mg glucose and azide (5×10^{-4} M)	389	310	80
Basal plus azide (5×10^{-4} M)	79	—	—
Basal	33	—	—

[1] The duration of the experiments was 570 minutes at which time respiration of all conidia had returned to the endogenous rate.

[2] Complete oxidation of 0.5 mg of glucose to CO_2 and H_2O would require 373 microliters of oxygen.

SUMMARY

Ziram inhibits a portion of the respiration of resting conidia of *F. roseum* at growth-inhibiting concentrations, but only the respiration accompanying new growth is affected in cells of *S. pastorianus*. The organic acids, citric, malic, fumaric, alpha-ketoglutaric, succinic, and pyruvic, were found in the mycelium of *F. roseum*. Alpha-ketoglutaric acid accumulated in cells treated with ziram. The effect of cycloheximide on the respiration of cells of *F. roseum* and *S. pastorianus* was similar to that of ziram on *F. roseum*. Sulfanilamide did not effect the oxygen uptake or dry weight increase of resting cells, but inhibited both processes in growing cells. The oxygen uptake by conidia of *F. roseum* was initially inhibited, and then stimulated by azide. The dry weight increase was inhibited. The possible effects of these compounds on metabolism are discussed.

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THE WASHINGTON HISTORY OF SCIENCE CLUB

In order to make it possible for those persons living in the Washington, D. C., area who are interested in the history, philosophy, and sociology of science to meet and exchange ideas, a History of Science Club has been formed and has embarked on its second series of meetings.

Dr. Raymond J. Seeger, of the National Science Foundation, Dr. Robert P. Multhauf, of the Smithsonian Institution, and Morris C. Leikind, of the Armed Forces Institute of Pathology, made up a temporary organizing committee until a constitution could be adopted and officers elected. At the fourth meeting of the group the following officers to serve from July 1957 to July 1958 were inducted into office: Dr. Multhauf, President; Dr. Edward Farber, Timber Research Laboratory, Vice-President; Mr. Leikind, Secretary-Treasurer.

About 40 persons are presently enrolled as members of the Club.

During the first year the following papers were presented:

December 6, 1956:

"The Origins of Art and Science in the Work of Leonardo da Vinci," by Dr. Raymond S. Stites, curator of education, National Gallery of Art.

"Aniline Dyes—Their Impact on Biology and Medicine," by Morris C. Leikind, medical historian and archivist, Armed Forces Institute of Pathology.

February 7, 1957:

"Benjamin Franklin as a Physicist," by Dr. Raymond J. Seeger, National Science Foundation.

March 19, 1957:

"Heavenly Clockwork—A Study of Mechanics in Medieval China," by Dr. Derek Price, consultant, Smithsonian Institution.

May 14, 1957:

"Goethe as a Scientist," by Prof. O. Temkin, Institute of the History of Medicine, Johns Hopkins University.

PALEONTOLOGY.—*Morphology and taxonomy of the foraminiferal family Elphidiidae.* MARY WADE, University of Adelaide, South Australia. (Communicated by Alfred R. Loeblich, Jr.)

(Received May 16, 1957)

The morphology of species of *Elphidium* and related genera is herein described, and the taxonomy of the group is discussed. *Elphidiella* Cushman is suppressed as a synonym of *Elphidium* Montfort. A new species of *Parrellina* Thalmann is described. Australian fossil species correctly referred to *Elphidium*, *Parrellina*, and *Notorotalia* are listed.

MORPHOLOGY

In the classification of the family Elphidiidae Galloway (1933, as Elphidiinae) the following characters are used: (1) The presence or absence of retral processes; (2) a complex canal system; (3) the diameter of the perforations in the wall; (4) the wall-structure; (5) the ornamentation; and (6) the coiling.

1. *The retral processes.*—Carpenter (1862, pp. 278–279; pl.4, fig. 28; pl. 16, figs. 6, 7, 9) regarded "retral processes" as "a set of processes . . . of sarcode . . . which extend backwards for a short distance from both the outer or lateral margins of each segment of the sarcode body." In describing *Elphidium craticulatum* (as "*Polystomella*") he said (p. 282): "The spiral lamina which forms the outer wall being modelled (so to speak) upon the surfaces of these retral processes, presents internally a corresponding series of grooves, which are deepest towards the posterior margin, and become rapidly shallower in passing towards the anterior margins, of each chamber." Evidence of retral processes, therefore, should not be sought on the outside of the test, but inside the chamber lumina. Later workers, concerned with the external appearance of the test rather than its detailed internal characters, have interpreted the external ridges which partially enclose the retral processes of protoplasm as "retral processes." An example is in the definition of the Elphidiidae given by Loeblich and Tappan (1953) and quoted by Smout (1955), "with retral processes projecting across the sutures." Parr (1950) spoke of *Parrellina* Thalmann, 1951 (as *Elphidioides* Parr 1950), having no "true retral processes." An examination of the inside of broken or dissected empty tests (including those in Parr's material) shows a row of small indentations around the septal sutures, which must have covered retral processes in Carpenter's sense. Such small hollows may house small retral processes without being noticeable externally, or, according to their size, they may underlie small ridges showing on the walls of the last few chambers, as in *E. craticulatum*, or very large ridges as in *E. crispum*.

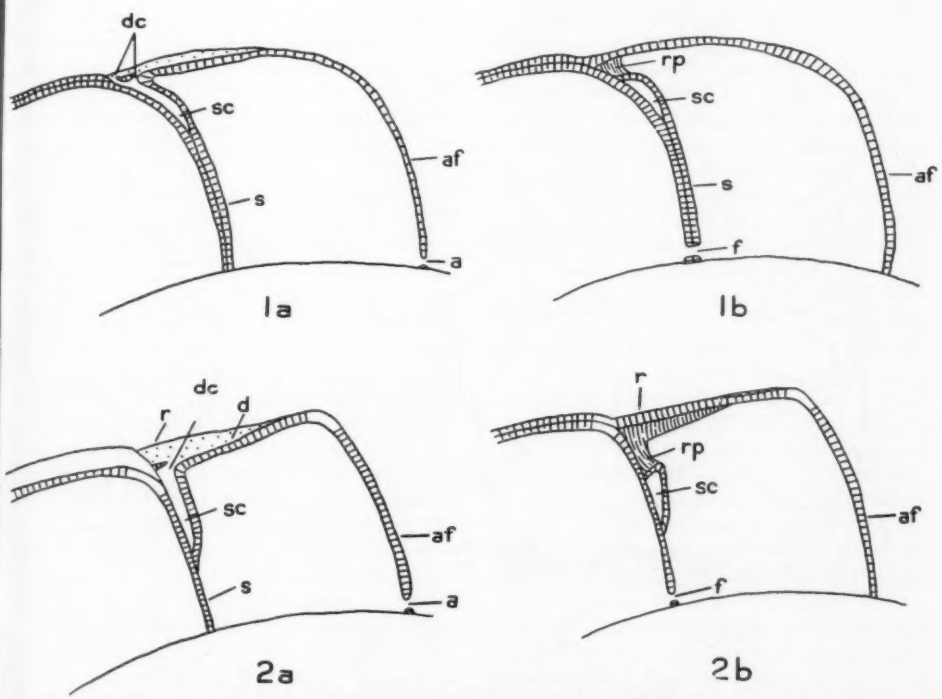
Carpenter (p. 282) differentiated between the internal "grooves" (underlying the external ridges) which house the retral processes of *E. craticulatum*, and the large, deep depressions of *E. crispum* "completed into tubes for part of their length by an additional lamella of shell given off from the septum". This difference seems to be one of size rather than structure (Figs. 1, 2, [7]). In fossil species the presence of indentations (grooves, tubes, hollows) in the chamber wall around the proximal edges of the chamber lumina is reliable evidence of protoplasmic retral processes. As the modification of the chamber walls indicates the retral processes, the indentations may be called retral processes without confusion.

After a detailed study of *E. crispum*, using both thin sections and internal moulds, Ujiié (1956) criticised Carpenter's results. He stated that the retral processes (which he called "septa-spirothecal stolons") lead into the lumen of the preceding chamber. These conflicting views are reconciled by a study of broken and dissected specimens. The retral processes of the last chamber end blindly against the septal face, being separated from the canal system by a fold of the septal flap (Figs. 2*b*, 3). In earlier chambers a minute pore appears by resorption in the septum at the base of each retral process. As still earlier chambers are investigated the pores are seen to enlarge until they occupy the base of each retral process, placing the chamber lumina in communication with each other through a series of short tubes, the lateral walls of the retral processes. It does not seem desirable to

introduce a new name such as "septa-spirothecal stolons" for retral processes in chambers other than the last, which have been placed in communication with the preceding chambers by partial resorption of the septa. The structure is not synonymous with those commonly called apertural or foraminal stolons in other groups of Foraminifera. Ujiié noted the breakdown of the septal walls in several species with large retral processes. It also occurs in species with moderate-sized retral processes but would be very difficult to observe, and may not occur, in those with very small retral processes. As Carpenter said, only the basal ends of the retral processes are tubular, the tubes being formed from the septal flap and the adjacent ridges on the chamber walls (Fig. 2). The remainder of the grooves below the tapering external ridges open into the chamber lumina, as Hofker (1956, p. 153) has again described. This fact does not fit Ujiié's interpretation of his internal moulds (1956, p. 271; Figs. 1, 2), since he states that the "septa-spirothecal stolons" are enclosed in complete cones which open to the surface by a fine pore. These pores have not been observed by the writer.

2. *The canal system.*—Carpenter and Ujiié both drew attention to the thickening of the outer wall of the test during growth. Carpenter (p. 280) noted that the "exogenous deposit" was "continuous with that of which the central nucleus is composed." He stated (p. 50, fig. 8) that this thickening of the wall characterized all the higher "vitreous" Foraminifera. Smout (1954, 1955) has shown that it is due to the enclosing of the whole test in a layer of shelly material each time a chamber is added; this is characteristic of the Rotaliidea as a whole, as Carpenter's description indicated.

The canal system is enclosed between the



FIGS. 1, 2.— 1*a*, *b*: *Elphidium craticulatum* (Fichtel and Moll); 2*a*, *b*: *E. crispum* (Linné). In each figure, *a* is a diagrammatic view of the last chamber cut through one of the surface depressions, and (*b*) a corresponding view cut through one of the ridges which separate the depressions. (Abbreviations: *a*—aperture; *af*—apertural face; *d*—surface depression; *dc*—diverging canal; *f*—foramen; *r*—surface ridge; *rp*—retral process; *s*—septum; *sc*—septal canal.) Approximately × 300.

initial wall of the chamber (the septal face) and the septal flap, that part of the succeeding chamber which is attached to the septal face. If retral processes are present to indent the septal flap and carry the outer chamber-wall which roofs them back to the previous chamber, the septal canal is deeply buried (Figs 1, 2) and communicates with the surface by diverging canals. If no retral processes are present the septal canals are roofed by part of the layer of shell material which encloses the test during growth; if this material becomes sufficiently thick diverging canals are again formed. In *Elphidiella arctica* (Parker and Jones) and *Elphidium subnodosum* (Münster) the roofing layer is perforate like the remainder of the wall (Hofker, 1956). In *E. subnodosum* it often breaks down near the margin and leaves the septal canals open as fissures. Hofker (1956) says that the septal canals of *E. arctica* lead to the surface at either side of the periphery of the test, and are not complete from one side to the other. He also says that the roofing layer is imperforate above the canal system in *Elphidium oceanicum* Cushman, and from his figure (pl. 24, fig. 3) this species appears to lack retral processes. It is hard to see an essential difference between these simply buried canal systems, and that so clearly figured by Hofker (1956, pl. 21, figs. 14, 15) for *Elphidiononion poeyanum* (d'Orbigny), type species of *Ephidiononion* Hofker.

The full development of elphidiid canal

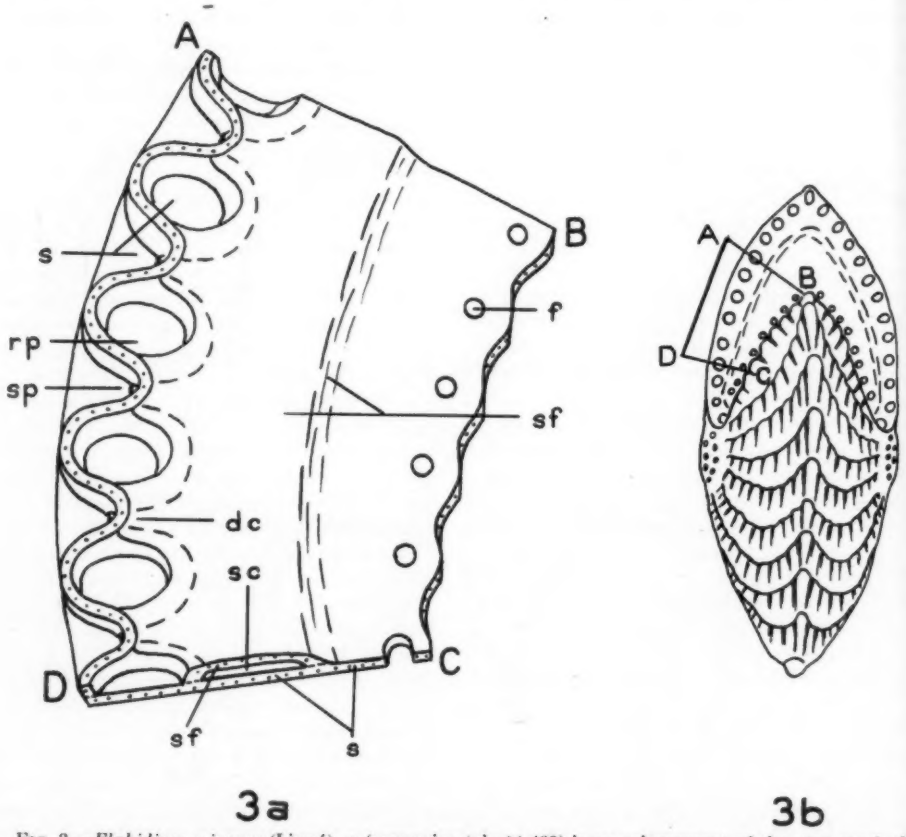


FIG. 3.—*Elphidium crispum* (Linné). *a* (approximately × 400) is an enlargement of the area marked ABCD in *b*. It represents the "apertural" view of a specimen lacking the last chamber. (Abbreviations: *dc*—diverging canal; *f*—foramen; *rp*—retral process; *s*—septum; *sc*—septal canal; *sf*—septal flap; *sp*—septal pore.)

systems, which is seen in *E. craticulatum*, was well described by Carpenter (1862). Its understanding has been amplified very ably by Hofker (1927, 1956) for numerous species of elphidiids. Typically there are spiral canals following the umbilical margins of the chambers. In forms with umbilical plugs, these give rise to straight, unbranched canals which lead to the surface of the plugs. A peculiarity of *Parrellina* Thalmann is the presence of anastomosing umbilical canals in place of spiral canals. Hofker (1956, p. 156) explains the lack of radial umbilical canals in *Elphidiella arctica* as due to the inner ends of the chambers overlapping the spiral canals, and this appears to be so in a number of the more involute forms. The spiral canals or the anastomosing canals give rise to subsutural septal canals at each septum. These may be complete, or those from each side may open to the surface by a pore on either side of the periphery, a condition which Hofker considers more primitive. In *E. subnodosum* the septal canals often become open fissures part-way to the periphery, though in other respects its canal system with well-developed spiral and umbilical canals is not primitive. Incomplete septal canals may be a specialized feature in this species at least.

In most species the septal flap does not cover the whole of the septal face of the preceding chamber, so that the septum as a whole is single-layered near the centre and base, and double near the outer edges, where it encloses the canal system. A few species which have massive walls have completely double septa, and these may enclose additional intra-septal canals between the two layers, as Carpenter (1862, pl. 16, fig. 1) figured in *E. craticulatum* and as can be seen in *Parrellina craticulatiformis*, n. sp. (Fig. 4, *2, 3, 6*). Brotzen (1948) showed a connection between the spiral canal and chamber lumen in *Elphidiella prima* (ten Dam), and Hofker (1956) states that this is typical of all advanced elphidiid canal systems. The writer has observed it in several species, including those of *Parrellina*.

3. *The perforations of the wall.*—Hofker (1956) places great emphasis on the significance of the size of the perforations of the wall, and asserts that the presence of relatively coarse pores is always associated with a relatively primitive canal system, not connected to the lumina of the chambers, the absence of retral processes, and the imperforate nature of that part of the test wall which roofs the canal system, and is divided into "pillars" by the septal pores. On the basis of these differences he removed several species from *Elphidium* to his genus *Elphidiononion* which he placed in the Nonionidae. The canal system, however, differs little from that of other elphidiids lacking retral processes, and Hofker has stated that the "pillars" roofing the canal system of *Elphidium oceanicum* are imperforate, like the "pillars" of *Elphidiononion*. It seems therefore that *Elphidiononion* is close to *Elphidium*.

4. *The wall-structure.*—The wall-structure was tested and found to be radial in topotypes of *Elphidiononion lidoense* (Cushman) and in *E. indicum* (Cushman); though no other species were available for examination, their agreement in described features suggests that they are likewise radial. This is typical of the Elphidiidae, and is a strong argument against a close relationship between *Elphidiononion* and the granular-walled *Nonion*.

5. *The ornamentation.*—Hofker (1956) showed that fine pustules of shell material, such as cover the whole surface of *Elphidium argentum* Parr, are quite a common form of ornamentation. In some species it is localized to beading on the older chambers and sutures. Some elphidiids have raised ridges of shell material on the surface of the chambers "situated between the openings of the canals, and thus coinciding with the retral processes," as Hofker stated. *Parrellina* Thalman has particularly thin, high bars of ornamentation. In some species they are a little irregular or may even be reticulate and only roughly coincide with the retral processes.

6. *The coiling.*—One uncoiled form, *Ozawaia* Cushman, has arisen whose young stages cannot be distinguished from *Elphidium*. Trochospirally coiled forms appear to have arisen several times. Of these *Faujasina* d'Orbigny and *Polystomellina* Yabe and Hanzawa are rather tenuously separated by the former being flattened on the evolute side and the latter flattened on the involute side. The species referred to *Notorotalia* Finlay are biconvex; their heavy ornamentation of transverse or reticulate ridges, usually with raised sutures, is strikingly similar to that displayed by *Parrellina imperatrix* (Brady) and related species, as both Finlay and Parr have said. It is most probable that they arose from

Parrellina independently of other trochoid forms. Hofker (1956, p. 163) has described the canal system of *N. clathrata* (Brady) very clearly. A similar bilateral canal system is present in *N. howchini* (Chapman, Parr, and Collins), which is widespread in the Middle Tertiary of South Australia. It has retral processes. *N. miocenica* (Cushman) from the Lower Miocene, Muddy Creek, western Victoria, has particularly large retral processes on the involute side. They are also present on the evolute side. The canal system is again bilateral (with septal pores on both sides). Another species which is widespread in the Middle Tertiary of South Australia is very close to, or may even be identical with, *N. tainuia* Dorreen (described from the Upper Eocene of New Zealand). It has retral processes with septal pores between them on the involute side, obscured by pustules of shell material which sometimes coalesce into transverse bars. The evolute side has no retral processes or septal pores, and no septal canal has been observed inside the test on the evolute side. As Hofker says that the canal system of *N. clathrata* develops on the evolute side after several chambers, the discovery of a species in which it is lacking is not surprising.

A form in which early planispiral growth is followed by annular growth is shown by the genus *Sherbornina* Chapman (Wade and Carter, in Press).

TAXONOMY

Brotzen (1948, pp. 70–71) has given the only satisfactory description of an early elphidiid, *Elphidiella prima* (ten Dam), Danian to Paleocene. *E. multiscissurata* Smout (1955), Maestrichtian, is well described externally, but details of the canal system are lacking. Apart from Hofker's descriptions (1927, 1956) the majority of the descriptions of Elphidiids are totally inadequate. As a result very little is known of the phylogeny of the group, or of what characters are generically important.

Hofker (1956), basing his opinion on Brotzen's description of *E. prima*, and on his own observation that species of *Elphidium* with both single and double rows of septal pores have the double rows in the microspheric generation, considers various characters "primitive" or "advanced." The lack of retral processes and double rows of septal pores such as are found in *E. prima*, together with incomplete septal canals like *E. arctica* (Parker and Jones), and very fine perforations in the walls, he considers "primitive." Relatively coarse perforations, retral processes, complete septal canals, well-developed spiral canals, and single rows of septal pores are considered "advanced." According to whether a species shows more "primitive" or "advanced" characteristics he allots it to a genus. Such a subjective approach allows room for endless arguments as to which characters really are primitive and which specialized (advanced); also as to which primitive characters outweigh which advanced ones. Hofker's usage results in the recognition of the genera *Elphidiononion*, *Elphidium*, and *Elphidiella* (he does not take *Parrellina* into account). Each of his three groups is fairly uniform in itself, but for the most part shares each of the "generic" characters with various species in other genera. Two distinctive characters appear to separate the species referred to *Elphidiononion* from those referred to *Elphidium* and *Elphidiella:* they have fewer, coarser perforations in the walls, and according to Hofker their canal systems do not communicate with the chamber lumina. From this it appears that *Elphidiononion* can be recognized as a genus close to *Elphidium*.

Cushman (1936, 1939) defined *Elphidiella* as "having two rows of openings at the sutures and with a thickened area between, without definite retral processes." He included in the genus the Recent *E. artica* (Parker and Jones) and similar Late Tertiary to Recent species. Numerous species of *Elphidium* have been described with some individuals having double rows of septal pores. They represent a wide variety of forms from stout-walled *E. craticulatum* (Carpenter) which has retral processes, to more fragile *E. kerguelenense* Parr which has none, and which Parr (1950, p. 373) said "is intermediate between *Elphidium* and *Elphidiella*."

Double rows of septal pores and the lack of retral processes are frequently found to occur independently, and confusion in classification has arisen as various authors applied one or the other character as the essential criterion. Smout (1955, pp. 207–208) redefined *Elphidiella* placing so much emphasis on the lack of retral processes that he removed it to the family which he considered ancestral to the Elphidiidae, the Miscellaneidae, in spite of its admittedly close relationship to *Elphidium*. Hofker (1956) emphasized the "primitive" canal system, septal pores, and lack of retral processes, while retaining it in the

Elphidiidae ("Polystomellidae") as a genus near (possibly ancestral to) *Elphidium*. Ujiié (1956) goes to the other extreme and places *Elphidium craticulatum* in *Elphidiella* presumably because of its double row of septal pores in the microspheric form, although it has retral processes. It may be difficult to decide whether a species in which the diverging canals are inclined to each other at a very low angle has one or two rows of septal pores. Ujiié illustrates this difficulty by drawing attention to "*Elphidiella*" *momiyamaensis* Uchio, in which "two rows of sutural pores can hardly be observed even in large specimens." No consistent differences separate *Elphidium* from *Elphidiella*, so "*Elphidiella*" Cushman should be suppressed as a synonym of *Elphidium* Montfort. From Brotzen's description of *Elphidium primum* ten Dam, it seems that this species can be included in *Elphidium*, extending the recognized range of the genus to Danian. It will be necessary to restudy other pre-Eocene species referred to "*Elphidiella*" to see whether they too can be referred to *Elphidium*.

Loeblich and Tappan (1953) drew attention to the fact that *Cribroelphidium* Cushman and Bronnimann (type species, *C. vadescens* Cushman and Bronnimann) is a synonym of *Elphidium* Montfort. This fact has since been overlooked by several writers.

EMENDATION OF THE GENUS PARRELLINA THALMANN

Parrellina imperatrix (Brady), Recent, Port Jackson, New South Wales, *P. verriculata* (Brady), Miocene, Muddy Creek, Hamilton, Victoria, and *P.* sp. from the Oligocene, Table Cape, Wynard, Tasmania, were studied in addition to Parr's type material of *Parrellina* ("*Elphidioides*" Parr, not Cushman). In these species the fine, high, wavy lines of ornamentation which cover the test do not always coincide with the retral processes. There is a canal system of septal canals and diverging canals, such as is found in *Elphidium*. All these are extremely compressed, semievolute forms; tangential sections parallel to the median plane reveal anastomosing canals in the poorly developed umbilical thickening, rather than clear spiral canals. The septal canals also appear to lead into one another in a dendroid fashion similar to that which is much more clearly seen in *P. craticulatiformis*, n. sp. (described below). In tests with heavily thickened walls the diverging canals do not open at the suture in fine septal pores, but wander on the lateral chamber-surfaces between the ridges of ornamentation. They do not occupy the position indicated by Parr (1950, fig. 7). In the figured specimen the dark lines which Parr figured as canals are an optical effect caused by the transluscent shell material of the surface ridges, and coincide with the retral processes. The septal and diverging canals can only be seen in the cut surfaces and from the exterior. They may send several branches to the surface of the test. Hofker (1956, p. 161) noted the fact that the canals enter the marginal spines in *P. imperatrix*. In *P. verriculata* there may be long, deep slits between the ridges, rather than canals. Recent specimens of *P. imperatrix* have a row of fine apertural pores at the base of the apertural face. There may be more than one row of foraminal pores in the septal face.

Parr's definition (1950, p. 373) of *Elphidioides* (*recte Parrellina* Thalmann) should be emended to read:

> Test planispiral, bilaterally symmetrical, involute to semi-involute; chambers numerous; sutures distinct, usually raised, connected across the intervening chamber surfaces by crossbars of rather wavy outline, sometimes anastomosing, which roughly coincide with the retral processes, the front of the last chamber also ornamented with raised ridges which radiate from near the base; wall calcareous radiate in structure; well-developed canal system with dendroid septal canals and diverging canals, septal pores small; aperture a series of fine pores near the base of the apertural face, often masked by the ornamentation.

Genus **Parrellina** Thalmann, 1951

Parrellina craticulatiformis, n. sp.

Fig. 4, *1–6*

Test large, up to 1½ mm in diameter, thickness more than half the diameter, in side view each half the diameter, in side view each half is rounded. There is a slight thickened ridge at the narrowly rounded periphery. The chamber walls are ornamented by long, thin, rather irregular cross bars up to three or four times as long as the narrow, usually raised sutures are wide. No retral processes have been seen. The very low apertural face is finely fluted and has a row of deep depressions along the basal suture. These depressions may lead into apertural pores, as thin sections show the foramina to be rows of pores in this position. The septum is double.

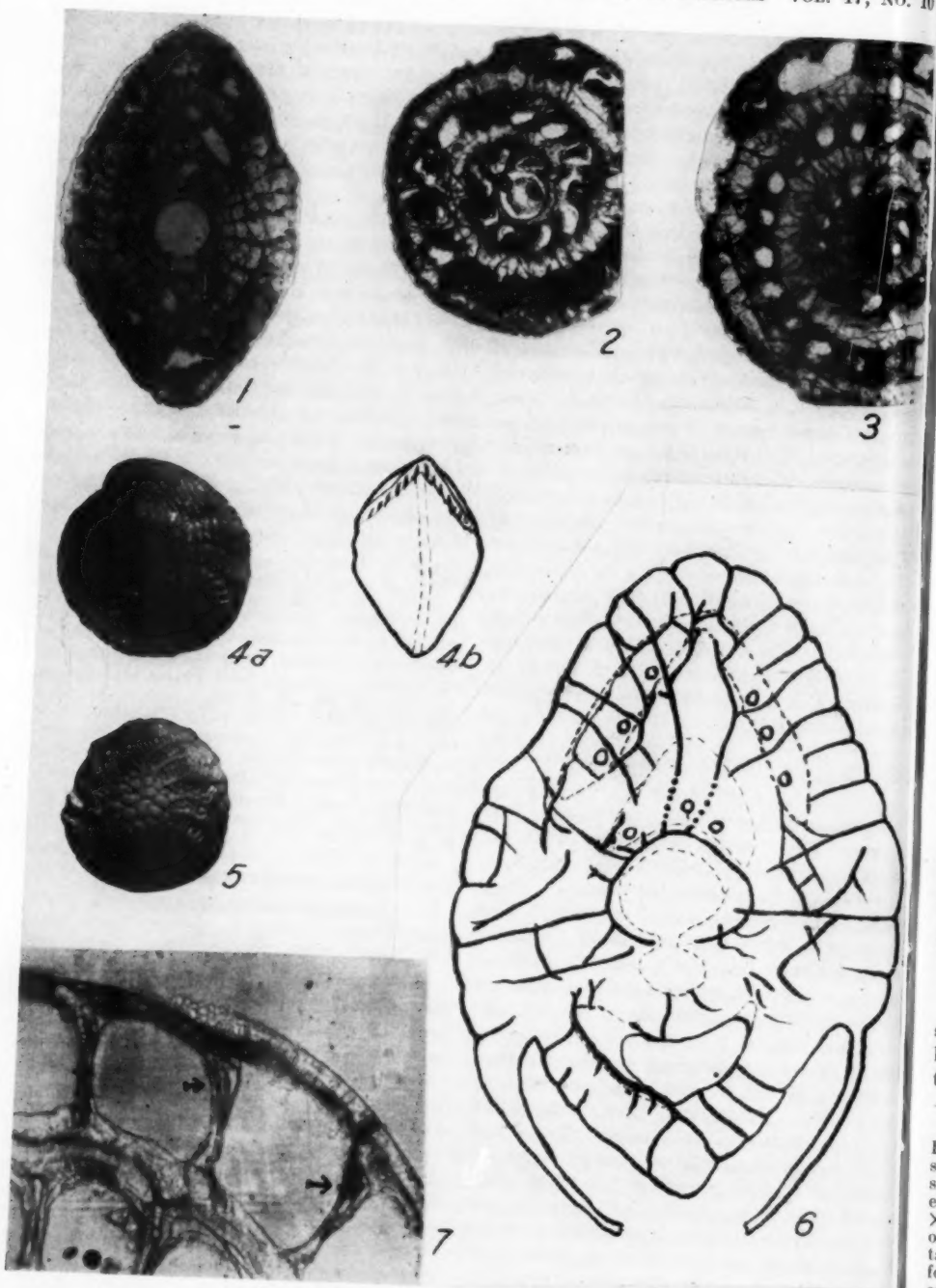


FIG. 4. (For explanation see opposite page).

The umbilical plugs are very large, formed by about fifteen to twenty bosses with pits between them. The pits are the openings of large radial umbilical canals some of which originate on either side of the initial whorl, smaller canals anastomose between the pillars of calcareous material which underly the bosses. Septal canals follow the outer edge of the septa, just below the septal sutures. No spiral canal is visible; the septal canals appear to join the small anastomosing canals in the umbilical plugs. Larger canals pass between the foraminal pores and across the septa between the two layers of which each consists. These canals branch and may join the septal canals, offshoots from both reaching the surface of the test as a row of fine pores (septal pits) along the suture. Near the periphery the branches (diverging canals) spread more widely in the thick spiral lamina, and their openings are not confined to the sutures. Some diverging canals lead into the lumina of chambers added above them; others pass between the layers of the septa, in the later whorls, rebranching, and extending to the surface of the test (Fig. 4, *2, 3, 6*). The main canal system is this dendroid system, which can be traced to its origin in the walls of the initial chamber, in both megalospheric and microspheric specimens. The chambers are narrow and numerous, they range from about eight in the first whorl to over twenty in the outer wall of large specimens.

Dimensions.—As follows:

Holotype, F15262, maximum diameter 1.06 mm, thickness 0.70 mm, Blanchetown.
Paratype, F15263, maximum diameter 1.31 mm, thickness 0.91 mm, Blanchetown.
Paratype, F15261, maximum diameter 1.36 mm, thickness 0.81 mm, Myponga Bore.

Occurrences.—Throughout the Lower Miocene section in the cliffs of the River Murray at Blanchetown, South Australia. Common. The type specimen from about 65 feet above sea level, from the lowest sample with *Lepidocyclina gippslandica* subsp. Lower Miocene.

Bore near Myponga, South Australia, 296 to 495 feet. Common. *L. gippslandica* subsp. is present. Lower Miocene.

Remarks.—*Parrellina craticulatiformis*, n. sp., is probably the species described as *Elphidium* sp. by Howchin and Parr (1938, p. 309, pl. 18, fig. 8), who had a single specimen from the Miocene of the Metropolitan Abattoirs Bore, Adelaide. As indicated by its specific name this species at first glance resembles *Elphidium craticulatum* (Brady) in its rotund proportions. Its ornamentation differs, however, and it lacks the clearly defined spiral canals of *E. craticulatum*, having anastomosing canals in the umbilicus in addition to the radial umbilical canals found in both species. Another difference is the subordination of the septal canals in *P. craticulatiformis* to a dendroid intraseptal canal system which I have not found in *E. craticulatum* (Recent, New Guinea), though Carpenter (1862, p. 285; pl. 16, fig. 1) described a similar one from his much larger specimens. The species Parr (1950) referred to "*Elphidioides*" (*recte Parrellina* Thalmann), are rather delicate and do not have a completely double septum, hence they do not have an intraseptal canal system. This makes the similarity of their anastomosing umbilical canals, and the dendroid way the septal canals lead into each other (through some of the diverging canals) more striking. Similarly the diverging canals often spread a long way in the spiral lamina, particularly near the margin. It seems that *P. craticulatiformis*, n. sp., is best placed in this genus, in spite of its lack of retral processes which must have been lost in this species.

SPECIES PREVIOUSLY DESCRIBED FROM AUSTRALIA

Described species of Australian fossil elphidiids have been investigated to check their generic assignations.

FIG. 4.—*1–6*, *Parrellina craticulatiformis*, n. sp.: (*1*) Vertical section of a megalospheric specimen F15277, showing the radial and anastomosing umbilical canals; (*2*) horizontal section of a megalospheric specimen, F15276, showing double septa and the dendroid canal system; (*3*) horizontal section, microspheric, F15275, cut at the side of the initial whorl to show the dendroid canal system radiating from the earliest part of the test; some cleavages are visible as straight dark lines in the spiral lamina (*1–3* approx. ×40); (*4*) holotype, F15262, ×30 (*a* lateral view, *b* Outline, showing thick test, blunt keel, and low, ornamented, apertural face); (*5*) specimen from Myponga, showing umbilical bosses and fine ornamentation; (*6*) drawing of vertical section F15274, ×100, showing dendroid intraseptal canal system, and foramina in the septa. 7, *Elphidium craticulatum* (Fichtel and Moll): The arrows point to septal canals enclosed between the septal face and septal flap, with a retral process on the peripheral side, as in Fig. 1*b*. × 200.

Elphidium adelaidense Howchin and Parr (1938), *E. rotatum* Howchin and Parr (1938), and *E. chapmani* Cushman (1936) were obtained from the Pliocene of the Adelaide Plains Basin, South Australia. *E. macellum* (Fichtel and Moll) var. *limbatum* Chapman (1907) is common in the Pliocene of Jemmy's Point, Kalimna, Victoria. *E. pseudonodosum* Cushman (1936) also occurs there and in the Pliocene at Muddy Creek, near Hamilton, Victoria. Topotypes of *E. crespinae* Cushman (1936) were obtained from the Miocene of Muddy Creek. It seems that *E. crassatum* Cushman (1936), which was also described from the Miocene of Muddy Creek, is synonymous with the larger variants of *E. crespinae*. *E. parri* Cushman (1936) is also present in the Miocene of Muddy Creek. All these species are correctly assigned to *Elphidium*, and all have true retral processes. No specimens of *Elphidium evolutum* (Chapman, 1913) were available.

No specimens of *E. subinflatum* Cushman (1936), which has the ornamentation typical of a *Parrellina*, were available, and only one specimen of the closely similar *E. pseudoinflatum* Cushman (1936), from the Miocene of Muddy Creek. This species has large septal pores and no ornamentation on the septal face; it is strongly involute with the umbilical regions depressed. It appears to be an *Elphidium* rather than a *Parrellina*, in spite of its thin, wavy ornamentation. It is not possible to give a firm opinion on the classification of these species until adequate material for thin-sectioning becomes available.

Parrellina imperatrix (Brady, 1884) is found rarely in the Pliocene at Jemmy's Point, Kalimna (Parr, 1950). *P. verriculata* (Brady, 1884) is found in the Miocene at Muddy Creek. A closely similar species (*P.* sp. of this paper) is both common and widespread in slightly older beds in South Australia and at Table Cape, Wynyard, Tasmania. No specimens of *"Elphidium" howchini* Cushman (1936) have been found. A closely similar species of *Parrellina* which lacks the transverse ornamentation on the apertural face, occurs in the Oligocene of Table Cape.

Notorotalia miocenica (Cushman, 1936) is common in the Miocene at Muddy Creek. *N. howchini* (Chapman, Parr, and Collins, 1934) is very common and widespread in the Middle Tertiary of South Australia, one specimen was found in the Pliocene of the Adelaide Plains Basin. *N.* aff. *tainuia* Dorreen (1948) is common and widespread in the Oligocene of South Australia.

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I am indebted to Prof. Sir Douglas Mawson for making available the Parr Collection of Antarctic Foraminifera, and to Dr. M. F. Glaessner for the loan of much material from his private collection, and of otherwise unavailable literature; also for his critical reading of the manuscript. Miss A. M. C. Swan very kindly made the drawings for Figs. 1–3.

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WOOD-BORING BEETLES

The Smithsonian Institution has recently obtained a large and important collection of wood-boring beetles, to be added to the entomological series of the United States National Museum. The new collection, numbering more than 100,000 specimens and representing about 16,500 species of this enormous group of insects, came from Frederich F. Tippmann, an engineer, explorer, and entomologist of Vienna, Austria. He assembled the collection over a period of 40 years, not only collecting personally in every country of South America and in Africa, Asia, and Europe, but also purchasing great rarities from many remote parts of the world.

The wood-boring beetles of this family, numbering in all about 25,000 species, comprise one of the economically most important groups of insects of the world. In the larval stage they attack wood and stems of woody and herbaceous plants, and a few of them eat seeds. It is on record that one small outbreak of one species, affecting only 8 square miles of forest, killed 45,000 trees, aggregating nearly 1,000,000 cubic feet of timber. Fig-growing is impossible in some parts of India because of the damage caused by another species. In one area of China 90 percent of all citrus trees are infested by a wood-borer, and many young trees are killed annually in spite of preventive measures. Other species attack rafters of houses, particularly in continental Europe, furniture, rustic garden work, telegraph poles, and orchids.

Not all species, however, are harmful, point out Smithsonian entomologists. Live-stem borers are used to control the spread of noxious plants such as lantana. Larvae of several groups speedily break down stumps and discarded logs in coniferous plantations, greatly enriching the soil and clearing the ground. Some kinds indicate to the forester that his trees are unhealthy and are the victims of more serious foes.

These beetles range in size from minute specimens about $\frac{1}{16}$ inch long to monsters 4 to 5 inches in body length with 8-inch antennae. Every conceivable color is represented, and many mimic the form of other beetles, wasps, flies, and so forth.

The newly acquired collection, together with others already assembled at the United States National Museum, will permit studies embracing the biology and distributional features of the wood-boring insects and will be available to interested students of beetles who wish to undertake studies in this group. It is only through long and careful study using a working tool such as this important collection, that scientists are able to learn about both the useful and destructive forms of insects and how to distinguish between them.

ENTOMOLOGY.—*Cockroach egg case from the Eocene of Wyoming.*[1] ROLAND W. BROWN, U. S. Geological Survey.

(Received June 19, 1957)

Alive or long since dead, cockroaches seem to get into the U. S. National Museum with comparative ease. Sometimes, of a morning, when I open my desk I am disagreeably startled to find a large individual of *Periplaneta americana* waving its long, sensitive antennae at me warily by way of what, with some reservations, might be called a blattoid greeting. If the insect is motivated by good feeling, that emotion is not reciprocated by me, for I wholeheartedly detest these pestiferous, prolific, and repulsive creatures. Their lumbering flight through the air, their quick, furtive dash to safety in the nearest, impossible crevice, and their well-known filthy, destructive habits are neither beautiful to behold nor pleasant to contemplate. Fortunately, in some quarters at least, they are kept under control by species of flies and wasps that parasitize their eggs.

Fossil remains of ancient cockroaches are not uncommon in the plant collections that come to the Museum from many different localities, particularly those in the coal measures of Paleozoic age. Most of these fossils are impressions of wings (tegmina), entire specimens being seldom found. Perhaps the wings, tough and without appreciable nutriment, were discarded by predators, or the soft body parts decayed before the insect could be entombed in sediments. Examples of cockroaches, sometimes 10 cm long, are included in nearly every museum restoration of a Carboniferous swamp with its ferns, calamites, lepidodendrons, cordaites, and other vegetation. The cockroach line, however, continued through the succeeding geologic periods to the present with its estimated 3,500 species. Some South American species of *Megaloblatta* contain individuals that equal those of the Paleozoic in overall size.

In such a plant collection, taken in 1949 by Dr. J. B. Reeside, Jr., of the U. S. Geological Survey, from reddish, baked shale lying above a burned coal bed in lower Eocene strata of Wasatch age about 18 miles north of Wamsutter, Wyo., I found a small, squarish capsule (Fig. 2) that seems identifiable only as the egg case (oötheca) of a cockroach. This capsule is 3 mm long and 2 mm wide, but somewhat longer at the top than at the bottom. The top, as the specimen is here oriented, is apparently the the dehiscent or sutural crest and is bordered by a narrow flange that is faintly undulant, fluted, or notched. Seven vertical lines, equally spaced, indicate the internal egg chambers. As only one side of the specimen is visible the beholder, knowing that the capsules of living cockroaches, viewed from above, are seen to consist of two rows of alternating compartments, may perhaps be somewhat disappointed. Such, however, is often the nature of fossil material for which appropriate allowance must be made.

The oöthecae of most cockroaches are protruded lengthwise, the sutural crest being toward the dorsal (upper) side of the parturient insect, as shown well by Roth and Willis (1954, pl. 5). Not all living species lay such external, chitinous packages. Those that do not are more or less viviparous, the young emerging from an internal oötheca enclosed in a brood pouch. Roughly, the fossil capsule can be matched by the small egg cases of some existing cockroaches, but, as the cases of living cockroaches differ greatly in size, shape, and ornamentation (Shelford, 1912, p. 283) it seems futile to guess about the relationship of the fossil to any living species. If the female that laid this oötheca was proportional to the egg case in size it must have belonged to a small-sized species.

Thus far I have found only five previous records of fossils purporting to be cockroach oöthecae. All these fossils are from the coal measures of the late Paleozoic. Three are illustrated by Handlirsch (1908, p. 181, pl.

[1] Publication authorized by the Director, U. S. Geological Survey. Grateful appreciation for help is acknowledged to Drs. Ashley B. Gurney, U. S. Department of Agriculture; R. E. Snodgrass, U. S. National Museum; and Louis M. Roth, U. S. Army, Natick, Mass.

18, fig. 49 [originally figured by Sellards, 1904, p. 133, fig. 25], from Pennsylvanian strata at Lawrence, Kansas; fig. 47 [later photograhed by Schlechtendal, 1912, pl. 4, fig. 32], from the Carboniferous at Dölau in Saxony; and fig. 48, from the Carboniferous at Wettin in Saxony). Two are illustrated by Pruvost (1919, p. 244, pl. 22, fig. 16, text fig. 34, from the Westphalian stage of the Carboniferous at Aniche, France; pl. 22, fig. 15, text fig. 35, from the Westphalian at Lievin, France [see also Laurentiaux, 1951, p. 193, pl. 1, fig. 1].

None of these five specimens, judged from the illustrations, is completely satisfying as a cockroach oötheca comparable to examples from living species. Except the two by Pruvost, the illustrations depict fragmentary and featureless material. Sellard's specimen is figured as a curved, irregular outline, 15 millimeters long and 5 millimeters wide, with only a dim suggestion of ornamentation along the upper (assumed) dehiscence margin and a rounded notch on the lower margin. I was unsuccessful in obtaining this specimen for examination and in eliciting any further information from Dr. Sellards. His original report contains no description of the specimen but says only that it "has a striking resemblance to the egg cases of modern cockroaches" (Sellards, 1904, p. 120, 134). One might compare it casually and doubtfully with the oöthecae of living species of *Latiblattella*.

Handlirsch's figure 47 might be interpreted as a wing fragment of a cockroach or other insect. It contains minute cross venation not visible in the photograph given by Schlechtendal. Handlirsch's figure 48 simulates a stack of small coins, except that the bottom segment is rounded. Viewed horizontally instead of vertically it could conceivably, by a stretch of imagination, be likened to the oöthecal structure of the living *Blaberus craniifer*.

Pruvost's two specimens are well illustrated. They are much alike and evidently belonged to the same or closely related species of whatever produced them. In 1913 he (1919, footnote, p. 247) identified one (his text fig. 35) as the tooth of a fish, *Ctenoptychius* sp., but later changed his mind in favor of a cockroach oötheca. In my untutored opinion his first thought was in the right direction. Both specimens, as oriented by Pruvost, have lower borders with small, rounded projections, and upper borders that are ragged and irregular. These borders are unlike the relatively regular, straight margins on the oöthecae of living cockroaches. By turning his illustrations upside down it is easy to imagine that they represent small, perhaps somewhat worn fish teeth with fairly distinct crown and root portions. However, an additional circumstance makes a decision difficult about the true identity of these objects. It is the ambiguous fact that abundant cockroach wings and fish remains were found in association with them. Incidentally, I also think that Pruvost was most likely mistaken in identifying his specimens on plate 4, figs. 1–5, as the pronota of an unclassified insect called *Omoptilus hispidus*. These seem to me to resemble or suggest the cephalothoraxes of such xiphosurids as *Belinurus*, *Limulus*, *Prestwichia*, and related forms (see Pruvost, pl. 23).

Laurentiaux (1951, p. 188) accepted the Pruvost specimens as authentic oöthecae and, consequently, considered them as proof that some Paleozoic cockroaches were an exception to the apparent general rule for those insects. When found entire the Paleozoic females have a fairly long ovipositor (Sellards, 1904, figs. 12, 13, 15;

1 2 3

FIG. 1.—Forewing or tegmen of a Paleocene cockroach from strata on Cherry Creek, 10 miles north of Terry, Mont., × 2. FIG. 2.—Egg case of an Eocene cockroach from strata 18 miles north of Wamsutter, Wyo., × 5. FIG. 3.—Forewing or elytron of a beetle from the same locality as Fig. 2, × 10.

Laurentiaux, 1951, pl. 1, figs. 2a, 2b; pl. 2, figs. 1, 2a, 2b; Zalessky, 1953, text figs. 1–7) and are, therefore, thought to have laid eggs in the fashion of some orthopterans, singly or in batches, in suitable places, instead of dropping them in a capsule, after the manner of most of our domestic cockroaches. This was the basis for the opinion that the oöthecal apparatus did not become perfected until the close of the Paleozoic or later. If now the Pruvost specimens are not oöthecae but fish teeth, Laurentiaux's arguments lose most of their force.

It would seem, therefore, that, of all these examples, the Eocene specimen I am here reporting comes closest to being an authentic cockroach egg case. No wings, except those of beetles (Fig. 3), were found with the specimen. Nevertheless, cockroaches were undoubtedly in existence there or near there at that time for their wings (Fig. 1) occur in underlying Paleocene strata of the Fort Union formation and in overlying Eocene strata of the Green River formation (Scudder, 1890, p. 216, pl. 6, fig. 25).

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The truths of the scientific church are not dogmas, but something put forward as provisional only, and which her most faithful children are welcome to disprove if they can.—S. P. LANGLEY.

ZOOLOGY.—*On the Newport chilopod genera.* RALPH E. CRABILL, Jr., U. S. National Museum.

(Received May 21, 1957)

There is a curious parallel between the work of William E. Leach and George Newport in England and that of Horatio C. Wood and Charles H. Bollman in the United States. The earlier pair, Leach and Wood, forged the initial shadowy framework within which the later men, Newport and Bollman, were to refine, to rearrange, and magnify in a flurry of short-lived activity. Probably the comparison should not be extended too far, though finally it is tempting to recall that each of the later men died prematurely and, one might say, as a result of his zoological interests, Bollman of malaria, in 1899, in Georgia while engaged in field work, and Newport in 1854 of a fever contracted while collecting specimens in winter.

As was Wood in America, so was George Newport the first outstanding monographist of the Myriapoda in England. And this is odd, for apparently each was primarily interested in something other than myriapods, Wood in botany, and Newport in insect physiology and amphibian embryology. Each fell prey to a brief, intense infatuation with myriapod systematics, and then each turned again abruptly to other interests. For some elusive reason the myriapods have had many such transient amours, though not all were happy, fruitful unions by any means.

Newport's reëvaluation of the higher chilopod categories, his presentation of new species drawn from remote parts of the world, and particularly his recognition of a number of new genera all served to establish the faint lines of a firmer categorical fabric than had existed previously. The handful of genera proposed by Linnaeus, Lamarck, Latreille, and Leach before him had been born of an undeniable novelty and preserved by little more than their youth in a generic void.

The Newport genera are important. They have lent themselves to three family and two subfamily names; many of their species are the most familiar chilopods in various parts of the world. Because details of publication have often been misrepresented in the literature,[1] and especially because the identity of the type species, and hence the content of these genera, seem to have received an often indifferent attention, it is desirable to review them.

Arthronomalus, 1844. (*10*, p. 193. Proposed without mention of included species.) Newport proposed a number of genera without stating specifically which species each should include. However, none of these is a *nomen nudum*, for each was accompanied by a brief key-diagnosis. The first species were assigned to *Arthronomalus* by Newport in 1845 (*12*, p. 430). Seven in number, they included *Geophilus longicornis* Leach, 1815, which was subsequently designated the genotype by O. F. Cook in 1895 (*3*, p. 74).

Apparently Newport distinguished between *Arthronomalus* and *Geophilus* chiefly on the basis of cephalic proportions and shape,[2] a practice which neither was unique to him nor was to stop with him, for as late as the 1880's Jerome McNeill and C. H. Bollman utilized often the same criteria in other geophilomorph categories. It was not until the mandibular and maxillary criteria had been disclosed that any real insight into the higher categories was gained.

Since the genotype of *Arthronomalus* today is regarded as a congener of *electricus* Linné, 1758, the type species of *Geophilus* Leach, 1814, the two are subjective synonyms, *Geophilus* of course having priority.

Branchiostoma, 1845. (*12*, p. 411. Proposed with four species.) This genus is the junior homonym of *Branchiostoma* Costa, which was proposed in 1834 for the reception of a cephalochordate. In 1893 Bollman suggested that *Rhysida* Wood, 1862, ought to be used instead (*1*, p. 171).

[1] In this connection I am deeply indebted to Mr. Francis Hemming, secretary of the International Commission on Zoological Nomenclature, for his generous assistance in discovering the true dates of publication of the 1844 and 1845 works. See References *10*, *11*, and *12*.)

[2] Viz, *Arthronomalus*, "Segmentum cephalicum subquadraticum, angulis rotundatis," as against *Geophilus*, "Segmentum cephalicum parvum, breve, subtriangulare, antice angustatum, postice dilatatum transversum. . . ."

Cormocephalus, 1844. (*10*, p. 193. Proposed without mention of included species.) In 1845 Newport assigned the first 13 species to his genus (*12*, p. 419). Of these, *rubriceps* was subsequently designated genotype by Pocock in 1891 (*13*, p. 229).

Gonibregmatus, 1843. (*8*, p. 180. Proposed with one species.) Only *cumingii* Newport was originally included in the genus; it is therefore the genotype by monotypy.

Henicops, 1844. (*10*, p. 192. Proposed without mention of included species.) Newport redescribed the genus in 1845 (*12*, p. 372), adding two new species, one of which was *maculatus*. Pocock subsequently designated this the genotype in 1901 (*14*, p. 451).

Heterostoma, 1844. (*10*, p. 193. Proposed without mention of included species.) The Newport name was preoccupied by an 1837 trematode genus, *Heterostoma* De Filippi. Many of the species assigned the Newport genus, today are referred to *Ethmostigmus* Pocock.

Mecistocephalus, 1843. (*8*, pp. 177, 178. Proposed with five species.) One of the initial inclusions, *punctifrons*, was subsequently designated genotype by R. V. Chamberlin in 1914 (*2*, p. 61). O. F. Cook's action of 1895, the selection of *Geophilus attenuatus* Say, 1821, as the type, is of course invalid, inasmuch as this name was not among those originally referred to the genus. It seems clear from this that Cook did not regard it important that a genotype be a charter member of a genus.

His paper of 1895 bears careful study. First, he reasoned that Say's nebulous *attenuatus* could not be *Geophilus* (=*Arenophilus*) *bipuncticeps* Wood, 1862, as Bollman had believed, and then that the Say species must be conspecific both with *Pachymerium ferrugineum* (C. L. Koch), 1847 and with *Geophilus* (=*Arcuogephilus*) *fulvus* (Wood), 1862. Actually, in lieu of the type, and working only from the original description, no one can be certain today of the identity of the Say species. I am inclined to agree with Bollman's point of view, to equate it provisionally with *bipuncticeps*.

Next, having decided that *attenuatus*, *ferrugineum*, and *fulvus* were all conspecific, and that the first should be the genotype of *Mecistocephalus*, Cook attempted to resolve the matter in the following way, "This disposition leaves the species hitherto called *Mecistocephalus* in need of a generic name . . . ," thereupon presenting as new *Dicellophilus*, *Lamnonyx*, and *Megethmus*.

Necrophloeophagus, 1843. (*8*, pp. 178, 180. Proposed as a subgenus of *Geophilus*, with one species.) Originally Newport included a single species, *longicornis* Leach, 1815, within *Necrophloeophagus*; therefore the genus is monobasic, and *longicornis* is its type.

Inasmuch as the same species is also the type of *Arthronomalus* (q.v.), the two genera are objective synonyms, *Necrophloeophagus* having priority. In addition, their genotype presently is considered congeneric with that of *Geophilus*, so that they are junior subjective synonyms of the Leach genus.[3]

I am not altogether convinced that *longicornis* and *electricus* belong in the same subgenus, for the former exhibits certain features that are more reminiscent of, say, *Arenophilus* spp. or even of the American *Geophilus varians* McNeill than of a typical *Geophilus*. I believe that a subgeneric division of *Geophilus* is feasible, but only desirable if it can be based upon the known world fauna, rather than upon the extremes of a restricted fauna which seems to characterize the attempts to date. Such a revision probably would involve a subgeneric distinction between *longicornis* and *electricus* in which *Necrophloeophagus* would be available for use.

Rhombocephalus, 1844. (*10*, p. 193. Proposed without mention of included species.) The earliest assignment of species to this genus was that of 1845 (*12*, p. 425, 426), when its author described the following as new: *viridifrons*, *gambiae*, *parvus*, *politus*, and *brevis*. As usual, none was selected as type. At different times toward the end of the century Pocock states *Scolopendra cingulata* Latreille, 1829, or *S. morsitans* Linné, 1758, to be the genotype. But since neither of these names was among those first assigned the genus in 1845, neither was available for subsequent designation (see Bull. Zool. Nomencl., **4**: 179–180, 1950, Concl. 69 (3) (a); p. 348, Concl. 31 (b)). Therefore I designate *Rhombocephalus viridifrons* Newport as the type-species, and inasmuch as *viridifrons* (=*cingulata*) is congeneric with the type of *Scolopendra*, i.e. *morsitans* Linné, the Newport genus becomes a junior subjective synonym of the Linnaean.

[3] The year of the proposal of *Geophilus* is generally given incorrectly, as is the identity of its true genotype (which is not *carpophagus* Leach, 1815). The genus was first presented in the obscure Brewster's Edinburgh Encyclopaedia of 1814 (5, p. 409) and originally included only *Scolopendra* (=*Geophilus*) *electrica* Linné, 1758, which is thus its type species by monotypy.

Scolopocryptops, 1844. (*11*, p. 275. Proposed without included species.) In 1845 the first five species were assigned the genus by Newport (*12*, p. 405), and according to the present regulations of the I.C.Z.N. (see reference above under *Rhombocephalus*), the type would have to be selected from that group. The earliest designation of a genotype was accordingly that of Lucas in 1849 (*7*, p. 444). His choice was *Scolopocryptops melanostoma* Newport, 1845, which means that since this species is congeneric with *sexspinosa* Say, 1821, and with *rubiginosa* L. Koch, 1878, all must bear the Newport name (and not that of its junior synonym *Otocryptops* Haase, 1887). From this it also follows that *miersii* Newport and its congeners required a new name, to which end *Dinocryptops* Crabill was proposed in 1953 (*4*, p. 96).

Theatops, 1844. (*10*, p. 193. Proposed without mention of included species.) Newport relegated the first species to *Theatops* in 1845 (*12*, p. 409). His action fixed *Cryptops postica* Say, 1821, automatically as the type-species (by subsequent monotypy).

Following is a nomenclatorial abstract of the foregoing: for details of pagination, etc., see the preceding discussions.

Arthronomalus, 1844. (*10*, p. 193.) [=*Geophilus* Leach, 1814.]
Genotype: *Geophilus longicornis* Leach, 1815.
Fixation: By subsequent designation of Cook, 1895.

Branchiostoma, 1845. (*12*, p. 411.)
A junior homonym of *Branchiostoma* Costa (Cephalochordata); replaced by *Rhysida* Wood, 1862.

Cormocephalus, 1844. (*10*, p. 193.)
Genotype: *Cormocephalus rubriceps* Newport, 1845.
Fixation: By subsequent designation of Pocock, 1891.

Geophilus Leach, 1814. (*5*, p. 409.)
Genotype: *Scolopendra* (=*Geophilus*) *electrica* Linné, 1758.
Fixation: Monotypy.

Gonibregmatus, 1843. (*8*, p. 180.)
Genotype: *Gonibregmatus cumingii* Newport, 1843.
Fixation: Monotypy.

Henicops, 1844. (*10*, p. 192.)
Genotype: *Henicops maculatus* Newport, 1845.
Fixation: By subsequent designation of Pocock, 1901.

Heterostoma, 1844. (*10*, p. 193.)
A junior homonym of *Heterostoma* De Filippi (Trematoda); replaced in part by *Ethmostigmus* Pocock, 1891.

Mecistocephalus, 1843. (*8*, pp. 177, 178.)
Genotype: *Mecistocephalus punctifrons* Newport, 1843.
Fixation: By subsequent designation of Chamberlin, 1914.

Necrophloeophagus, 1843. (*8*, pp. 178, 180.) [=*Geophilus* Leach, 1814.]
Genotype: *Geophilus longicornis* Leach, 1815.
Fixation: Monotypy.

Rhombocephalus, 1844. (*10*, p. 193.) [=*Scolopendra* Linné, 1758.]
Genotype: *Rhombocephalus viridifrons* Newport, 1845.
Fixation: By present designation.

Scolopocryptops, 1844. (*11*, p. 275.)
Genotype: *Scolopocryptops melanostoma* Newport, 1845.
Fixation: By subsequent designation of Lucas, 1849.

Theatops, 1844. (*10*, p. 193.)
Genotype: *Cryptops postica* Say, 1821. [=*Theatops postica* (Say).]
Fixation: By subsequent monotypy.

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(11) ———. Trans. Linn. Soc. London **19:** 265–302. 1844 [after May]. [Included in the volume labeled 1845, but actually issued sometime after May, during 1844.]

(12) ———. Trans. Linn. Soc. London **19:** 349–439. 1845. [According to the librarian of the Linnaean Society, *fide* Hemming, volume 19, nominally of 1845, was in fact issued as follows: Part I, pp. 1–80, 1842; Part II, pp. 81–170, 1843; Part III, pp. 171–302, 1844; Part IV, pp. 303–537, 1845.]

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ZOOLOGY.—*A redescription of two parasitic copepods from Bermuda.*[1]

HARRY C. YEATMAN, University of the South. (Communicated by Fenner A. Chace, Jr.)

(Received June 20, 1957)

When investigating the littoral and neritic copepods of Bermuda during July and August 1955, I became interested in the apparent scarcity of parasitic copepods on fishes observed. A preliminary collection of 2 squirrelfishes, *Holocentrus ascensionis* (Osbeck); 1 hamlet, *Epinephelus striatus* (Bloch); 4 gray snappers, *Lutianus griseus* (Linnaeus); 7 breams, *Diplodus argenteus* (Cuvier and Valenciennes); and 1 chub, *Kyphosus sectatrix* (Linnaeus) was examined for parasitic Crustacea. The last three species carried an abundance of parasitic isopods, *Exocirolana mayana* (Ives), but none was infested with copepods. These isopods have been sent to the U. S. National Museum (99587). Wilson (1913) found that isopods were quite abundant and that parasitic copepods were few on the fish he examined at Jamaica, B.W.I.

On August 17, 1955, David Menzel, a graduate student at the University of Michigan, collected 2 female copepods from a tiger rockfish or gag, *Mycteroperca tigris* (Cuvier and Valenciennes), taken off North Rock, Bermuda. These were given to me and proved to be perfect specimens of *Dentigryps curtus* Wilson. These differed from Wilson's (1913) original description chiefly in the armature of the feet and caudal rami. Through the kindness of the Division of Marine Invertebrates of the U. S. National Museum, I was able to examine the type specimen and two paratype specimens, and these showed by the presence of attachment bases that some prominent setae had been broken off.

It is very desirable to redescribe a species if the original specimens were incomplete in structure, and even more desirable if there is danger that someone will describe a complete specimen of this species as a new species. This has been done many times in the past. Taxonomic literature is already overcrowded with synonyms.

[1] Contribution no. 232 from the Bermuda Biological Station.

Specimens of *Lepeophtheirus dissimulatus* Wilson were also lent by the U. S. National Museum. This species is redescribed here because of its rather close resemblance to the complete specimens of *Dentigryps curtus*. I was unable to obtain specimens at Bermuda.

Wilson (1936) found a single specimen of *Caligus curtus* Muller in a deep-water plankton haul made by Dr. William Beebe at Bermuda. There is no other Bermuda record of this species, but it may occur there on deep-water fishes even though its common hosts, cod, hake, haddock, pollack, halibut, and barn-door skate, have not been reported from Bermuda.

These three species are the only ones reported from Bermuda. I did see a copepod taken from a shark, but unfortunately it was not obtained for examination.

The author wishes to express thanks to David Menzel for the specimens of *Dentigryps curtus*, to Dr. Fenner A. Chace, Jr., and Dr. Thomas E. Bowman of the U. S. National Museum for the loan of type specimens and literature, to Dr. William H. Sutcliffe, Jr., director of the Bermuda Biological Station, for the privileges of the laboratory and many courtesies. He also wishes to thank the National Science Foundation and the University of the South Research Fund Committee for financial aid in the study of certain groups of copepods of which this investigation is only a small part.

Dentigryps curtus C. B. Wilson (1913), new description

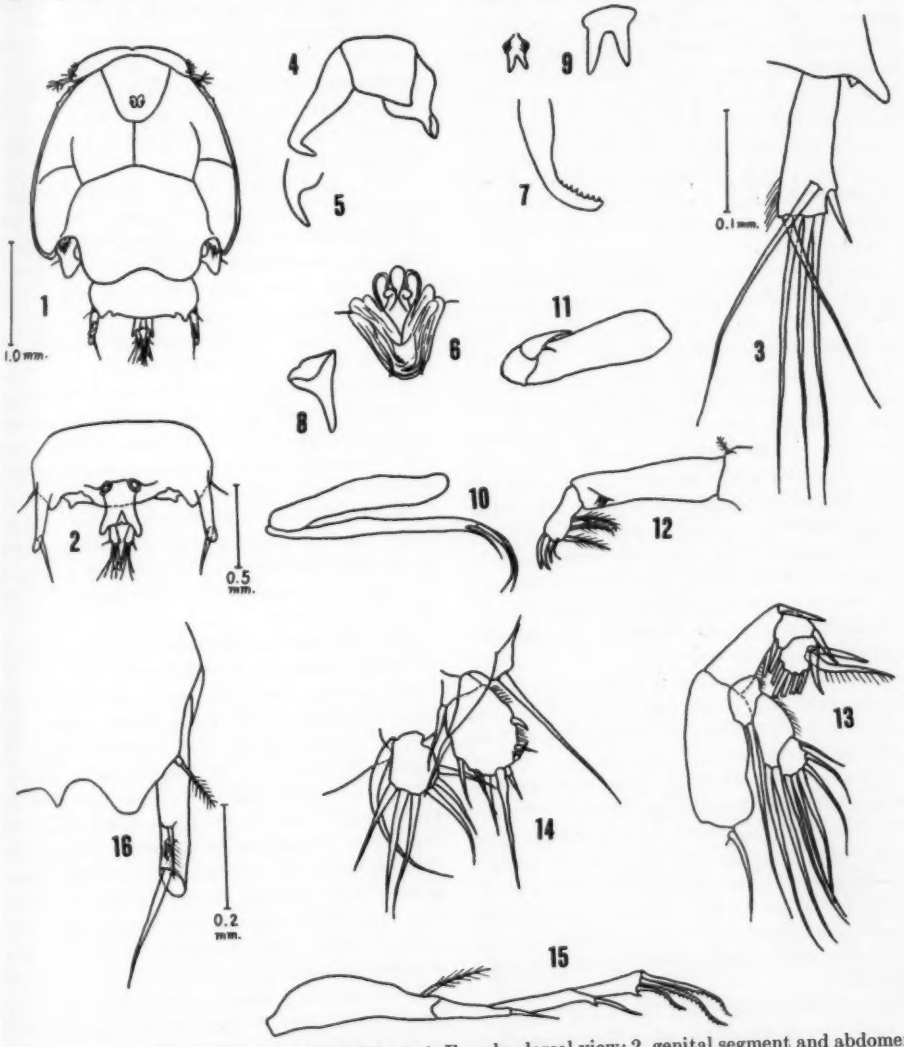
Figs. 1–16

Specimens examined.—One mature female (type specimen, U.S.N.M. 43595) collected from mouth of yellow-finned grouper, *Mycteroperca venenosa apua* (Bloch) by Dr. Edwin Linton, Bermuda Islands, July 27, 1903.

Two mature females (paratypes, U.S.N.M. 42328) collected from *Mycteroperca v. apua* by Louis L. Mowbray, Bermuda Islands, July 27, 1903.

Two mature females (U.S.N.M. 100899) collected from tiger rockfish or gag, *Mycteroperca tigris* (Cuvier and Valenciennes), taken off North Rock, Bermuda, at a depth of 30 fathoms by David Menzel, August 17, 1955. Identified by H. C. Yeatman.

Description of female.—Length 2.85 to 3.60 mm, not including terminal setae of caudal rami. General body form elliptical. The widely truncated posterior margin of the genital segment gives the appearance that some of the posterior body is missing. Carapace is about as wide as long and much longer than the remainder of the body. Grooving of the carapace as in Fig.



FIGS. 1–16.—*Dentigryps curtus* C. B. Wilson: 1, Female, dorsal view; 2, genital segment and abdomen, ventral view; 3, right caudal ramus, dorsal view; 4, second antenna; 5, lateral hook; 6, mouth tube; 7, mandible; 8, right first maxilla; 9, furca from two different specimens; 10, second maxilla; 11, maxilliped; 12, first leg; 13, second leg; 14, third leg; 15, fourth leg; 16, fifth leg, dorsal view. (Figs. 3, 13, and 14 drawn to same scale. Figures 4–6, 8–12, 15, and 16 drawn to same scale.)

1. Frontal plates are without lunules and are well developed. Eyes fairly small and anteriorly placed. In none of the specimens I have examined are the eyes as large and round as Wilson (1913) shows in his figure 127.

Fourth and fifth body segments fused with the genital segment and all three covered by a single dorsal plate, which is as wide as the thoracic portion of the carapace. This character enables this species to be distinguished from *Lepeophtheirus dissimulatus* at a glance (see below). Posterior border of genital segment is widely truncated and bears at its posteriolateral corners a small inner knob, a larger middle knob, and a very large outer conical prong. These prongs are somewhat more ventral than are the knobs. They represent the fifth legs and their armature is described below.

The single abdominal segment is attached to the posteroventral surface of the genital segment (Fig. 2) and is about 1½ times as long as wide. Its posterolateral corners protrude posteriorly. Caudal rami are about three times as long as the width at the middle. The distal end is noticeably wider than the base. The inner distal margins are hairy. Wilson (1913) described and drew three terminal setae on each ramus, but the type and paratype specimens show by attachment bases that 3 more appendages belong on each. My undamaged specimens show one outer subterminal spine, one subterminal dorsal seta and four terminal setae on each ramus (Fig. 3).

Egg strings resemble those of *Lepeophtheirus dissimulatus* (see below).

First antennae short and armed as in Fig. 1. Second antennae stout and composed of two well-defined segments. The terminal end bent abruptly near its end to form a claw.

A lateral prehensile hook is present posterior to each second antenna. This hook is slightly curved medially and lacks any appendages. This hook, found in the Caligidae, was earlier wrongly described by Wilson (1905) as the first maxilla. He corrected the error before he described this species, but some fairly recent descriptions of specimens of Caligidae have copied his early mistakes.

Mouth tube is short and blunt and its details of structure are difficult to see without dissection mandible with about eight or nine teeth.

First maxillae are undivided, almost straight prongs and are posterolateral to the mouth tube.

Second maxillae are 2-jointed; the second joint longer and more slender than the first and armed distally with two terminal setae and one subterminal spine. These setae, unlike the spine, are separated from the segment by a distinct joint.

Maxillipeds are stout. The terminal claw bears a small spine on its inner margin.

The furca consists of two smooth prongs and a base that may or may not be marked with circular striations. The caudal rami of free-living copepods are sometimes called furcal rami. The furca of parasitic copepods is not to be confused with the caudal rami.

First legs consist of a basal segment bearing a short spine and a two-segmented exopod. The proximal segment bears a short comb of small setae near its distal end. The second segment is armed with three spines and one seta at its distal end and three lateral setae.

Second legs with 3-segmented exopod and endopod and armed as in Fig. 13.

Third legs as in Fig. 14. Terminal segment of exopod is armed with nine appendages (spines and setae), not six as in Wilson's (1913) figure 133. Terminal segment of endopod is armed with six appendages, not four.

Fourth legs consist of only one slender ramus. Basal segment bears a seta or spine near the distal end. Second and third segments bear a terminal spine each, and fourth segment with three distal spines.

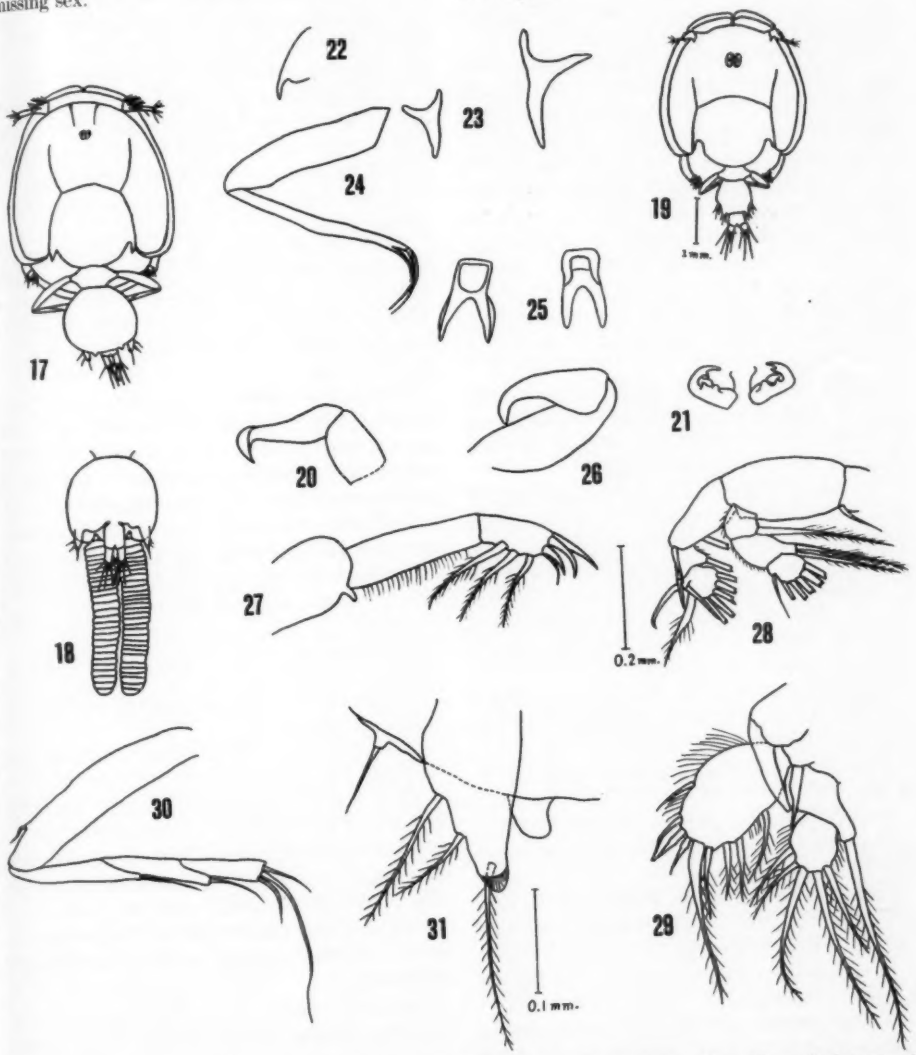
The fifth legs were described by Wilson (1913) as being "perfectly smooth" and "cut off obliquely at the tips." In one of his females he found "a single, long, non-plumose spine near the tip of each prong." His drawings show no appendages attached to this prong. A quick glance at the fifth legs of my undamaged specimens would make an examiner think that here was a new species within the genus *Dentigryps*. Wilson, however, overlooked some of the small setae that are actually present in his type specimen. The other missing appendages (spines and setae) indicate their former presence by their attachment bases. A dorsal view of an undamaged fifth leg shows a short dorsolateral seta on a small papilla near the base of the long, distinct segment. The long segment bears one short, straight seta attached just beyond the middle and a shorter curved seta between it and the oblique end. A long smooth spine is attached to

the proximal portion of the slanting end of the segment (Fig. 16).

The male as yet remains unknown. More extensive collecting and examination of the groupers around Bermuda will undoubtedly obtain this missing sex.

Distribution.—Bermuda Islands on yellow-finned grouper, *Mycteroperca venenosa apua* (Bloch) and tiger rockfish or gag, *Mycteroperca tigris* (Cuvier and Valenciennes).

Dry Tortugas, Fla., on yellow-finned grouper, *M. v. apua*.



FIGS. 17–31.—*Lepeophtheirus dissimulatus* C. B. Wilson: 17, Female, dorsal view; 18, genital segment, egg sacs, and abdomen, ventral view; 19, male, dorsal view (after Wilson, 1905); 20, second antenna of female; 21, second antenna of male (after Wilson, 1905); 22, lateral hook; 23, first maxillae from two different specimens; 24, second maxilla; 25, furca from two different specimens; 26, maxilliped; 27, first leg; 28, second leg; 29, third leg; 30, fourth leg; 31, fifth leg, ventral view. (Figs. 20, 22–28, and 30 drawn to same scale. Figs. 29 and 31 drawn to same scale.)

Lepeophtheirus dissimulatus C. B. Wilson (1905), new description

Figs. 17–31

Specimens examined.—Three mature females, U.S.N.M. 42073. Collected by E. Linton July 11, 1903, from red grouper, *Epinephelus morio* (Cuvier and Valenciennes), Bermuda Islands. Identified by C. B. Wilson.

One mature female, U.S.N.M. 42276. From gills of yellow-finned grouper, *Mycteroperca venenosa apua* (Bloch), Bermuda Islands, September 27, 1903. Identified by C. B. Wilson.

Description of female.—Length 2.40 to 3.54 mm, not including terminal setae of caudal rami. Carapace as wide as long or slightly longer and much longer than the remainder of the body. Grooving of carapace as in Fig. 17. Frontal plates well developed and without lunules. Eyes small and anteriorly placed. Free thoracic segment short and more than a third as wide as genital segment.

Genital segment more or less spherical. Its posterior margin bears two small medial projections and 2 conspicuous lateral projections which represent the fifth legs (see below).

The single abdominal segment small and attached to the posteroventral surface of the genital segment. Caudal rami about twice as long as wide and armed with 4 fairly long terminal setae. It is possible that a fifth seta is present and has been broken off. If so, its attachment base is very difficult to see. The posterior inner margins of these caudal rami are hairy.

Egg strings are long and wide and are attached at points dorsolateral to the abdomen; 15 to 30 eggs are present in each string.

First antennae of two segments and armed as in Fig. 17.

Second antennae of two segments with a strongly curved terminal hook. These segments bear neither spines nor setae.

Lateral prehensile hooks, which were wrongly called first maxillae by Wilson (1905), are small and not armed with setae.

First maxillae are conspicuous, slightly inwardly curved spines.

Second maxillae are elongate and consist of two segments. The basal segment is wider but shorter than the terminal segment. The distal end of the second segment is armed with two long terminal setae which are jointed at their bases and a shorter curved subterminal spine which is not separated from its segment by a joint.

Furca with branches slightly laterally inclined. Branches are slightly more than half the furcal length and may or may not bear a slight wing or thin ridge on their outer margins.

Maxillipeds consist of two segments, the distal, hooklike segment is shorter than the proximal and not armed with setae or spines.

First legs consist of a basal segment bearing a short unjointed spine and a 2-segmented exopod. The terminal segment bears three spines and one seta at its distal end and three lateral setae.

Second legs with 3-segmented exopod and endopod and armed as in Fig. 28.

Third legs as in Fig. 29. Terminal segment of exopod is usually armed with nine appendages (setae and/or spines) instead of the five that Wilson (1905) shows in his figure 271. Terminal segment of endopod is armed with five appendages as Wilson shows.

Fourth legs consist of only one ramus. Basal segment with a small spine or seta on outer margin near distal end. Second and third segments with a terminal spine each, and fourth segment with three distal appendages.

Fifth legs, mentioned above, are not separated from the genital segment by a joint. There is a lateral seta on a tiny papilla and a subterminal seta and two lateral setae on a much larger papilla.

Description of male.—Length about 2.5 mm. Similar to female, but with free thoracic segment about as wide as genital segment which is squarely truncated posteriorly.

Second antennae longer than in female and branched (Fig. 21).

Fifth legs as in female, but more anteriorly placed and apparently lacking the outer seta.

Sixth legs consist of a pair of papillae, one at posterolateral margin of genital segment on each side. This papilla is armed with three spines.

Distribution.—Charles Island, Galapagos Islands, on white-spotted serranus, *Epinephelus labriformis.*

Bermuda Islands on Nassau grouper, *Epinephelus striatus* (Bloch); red grouper, *Epinephelus morio* (Cuvier and Valenciennes); yellow-finned grouper, *Mycteroperca venenosa apua* (Bloch).

Dry Tortugas, Fla., on the smooth trunkfish, *Lactophrys triqueter* (Linnaeus).

DISCUSSION OF SCARCITY OF COPEPOD PARASITES ON BERMUDA FISHES

Only the two above redescribed species of copepods have been reported from Bermuda fishes, and, as mentioned above, another species, *Caligus curtus*, was collected in a plankton net. Without checking collecting data and the environmental condititions, one is tempted to ask whether they are really scarce and, if so, why are they scarce? Perhaps the proper species of fishes have not been examined or are not present at Bermuda. Some species are commonly infested with copepods and others rarely, if ever, carry copepods. Sharks and rays nearly always carry parasitic copepods. The former are not particularly common at Bermuda, and only occasional specimens of rays consisting of two species have been reported. Next, one asks whether there are common species of fishes at Bermuda that are reported to be hosts of copepods at other localities.

Perhaps insufficient numbers of fishes have been examined. A. S. Pearse (1951) examined 368 fishes of 73 species at Bimini, Bahamas. Of these, 171 individuals of 23 species carried 290 copepods, but 140 fishes of 50 species carried none.

Perhaps the Bermuda fishes are examined too late after capture and by inexperienced copepod collectors. A good many parasitic copepods, especially those of the families Caligidae and Argulidae, will crawl off a dying fish and escape into the surrounding water or into the bottom of a boat or fishbox. Of course, a collector should be able to recognize parasitic copepods and look for them in the proper parts of the fish.

Edwin Linton (1905) spent July and August of 1901 and 1902 at Beaufort, N. C., examining 2,051 fishes of 59 species for all types of parasites. Of these, 17 species of 16 genera were carrying parasitic copepods. Some of these fishes were heavily infested with copepods.

In July and August 1903, Linton (1907) examined 263 fishes of 53 species at Bermuda. Of these, 130 fishes of 20 species have been proved to be hosts of parasitic copepods at Beaufort, N. C.; the Dry Tortugas, Fla.; Bimini, Bahama Islands; and Montego Bay, Jamaica (see bibliography). Two of these fishes carried two copepods each—a total of 4 copepods from 263 fishes examined by a man experienced in finding copepods and other parasites.

Most copepods which are parasitic on fishes do not confine their preference to a particular species but may be found on any species within a genus, or on any species within a family, or even on rather unrelated species of fish. Collecting records are full of evidence to substantiate this. If genera instead of species of fishes are counted, Linton's Bermuda catch included 193 fishes of 24 genera which contain proved hosts of copepods.

Many authors simply list the fish hosts which harbor copepod parasites and omit those which are free of such. Nevertheless, these lists furnish useful information for comparison purposes.

C. B. Wilson (1913) at Jamaica listed 26 species of fishes from which he obtained copepods in 1910. Of these, 19 are found at Bermuda and many are common. Of the 7 species not found at Bermuda, 6 of their genera are represented.

Wilson (1935) examined collections of parasitic copepods secured from Dr. H. W. Manter and Dr. O. L. Williams at the Dry Tortugas, Fla. Of the 30 species of fishes found infected with parasitic copepods, 19 are reported from Bermuda and 6 of these are of rare occurrence. Eleven are not present in Bermuda, but the genera of four of these are represented. In other words, 13 of these species are common in Bermuda and should yield copepods.

A. S. Pearse (1951) listed 23 species of copepods infesting fishes at Bimini Bahamas. Of these, 17 species are found at Bermuda plus two genera represented by different species.

The above information indicates that the proper copepod hosts are present at Bermuda, but that examination of more specimens is very desirable. Emphasis should be on examination of the jolthead porgy, *Calamus bajanado* (Bloch and Schneider); the great barracuda, *Sphyraena barracuda*

(Shaw); and species of sharks, snappers, groupers, puffers, and mullets which usually carry many copepods.

The possibility of undesirable environmental conditions should be considered if future extensive collecting proves that parasitic copepods are as scarce as they now appear to be.

Wilson (1905) stated that copepods of the family Caligidae are quickly killed by a rise of a few degrees in temperature and that A. Scott gives 16° C. as the upper limit for *Lepeophtheirus pectoralis*. Experiment has shown that other species do not differ much from this, some having upper tolerance limits of 18° or 20° C. This susceptibility to warm water may limit the distribution of these copepods to cool waters either at considerable depths or at higher latitudes. Most of the shallow water at Bermuda is considerably above 20° C., and it is notable that most of the copepod-infested groupers at Bermuda were caught in fairly deep water. My two specimens of *Dentigryps curtus* were collected by D. Menzel from a gag taken at a depth of 30 fathoms.

One theory concerning the scarcity of parasitic copepods on Bermuda fishes holds that many of the planktonic nauplius stages are carried away from Bermuda by the currents before they can reach the stage which attaches to host fish.

As mentioned above, the isopod *Exocirolana mayana* (Ives) commonly infests groupers, snappers, breams, and chubs at Bermuda. Why are these common and parasitic copepods rare on Bermuda fishes? The answer may be concerned with the differences in life histories of the two groups, or with differences in physiological requirements, or with both. The larval stages (nauplii) of parasitic copepods may be more planktonic than the larval stages of this species of isopod. If so, there is more chance that the former will be carried away by ocean currents.

As mentioned above, many species of parasitic copepods cannot tolerate high temperatures, and thus their distribution may be limited to the cool water outside the encircling reefs. Consequently they may be subjected to more currents which tend to sweep the larvae away.

Boden (1952) found that salinities and temperatures in the Bermuda "lagoon" were consistently higher than in outside waters in the summer. He shows that the currents within this lagoon become cooled by contact with the cold ocean water at the platform margins and thus sink and return to the lagoon instead of flowing out to be carried away, mixed with oceanic currents. This effectively conserves much of the insular plankton in the summer when reproductive activities of most marine organisms are at their maximum.

Plankton volumes were consistently higher within the lagoon than at the outer stations.

If some parasitic copepod species are confined to the outer cool water by temperature barriers, their chances of becoming numerous are much less than if they were able to live and reproduce within the lagoon.

My specimens of isopods were collected in relatively warm bays which are fairly calm even during storms. Whether or not these isopods can tolerate cold or deep water conditions has not been determined.

Finally, the possibility of excessive predation on parasitic copepods must be considered. Beebe and other observers, including myself, have observed the butterflyfish, *Chaeton capistratus* Linnaeus, eating crustacean parasites from the sides and from inside the mouths of gray snappers, *Lutianus griseus* (Linnaeus). These butterflyfishes are common about the harbors and inner reefs of Bermuda. There is some evidence that parasitic isopods which commonly infest Bermuda fish may eat copepod parasites of fishes. Some are very voracious and will even bite a collector's hand.

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ENTOMOLOGY IN WORLD WAR II

Since the start of World War II man has gone far toward the conquest of an enemy in some ways more vicious than any human foe—the insect. More than a million-and-a-half American soldiers were put out of action—many permanently—by insect-transmitted diseases during the progress of hostilities. Deaths in some areas exceeded those from wounds and accidents.

The story of the remarkable progress during the war, when balance of battle several times depended on beating the disease-carrying insects as well as Japanese or Germans, is told by Col. Emory C. Cushing, U. S. A., Ret., in a publication prepared under the general direction of a committee of the Entomological Society of America and the American Association of Economic Entomologists and recently issued by the Smithsonian Institution. Some of the victories, Colonel Cushing points out, probably represent permanent gains. Others may be temporary as insects adjust to the new weapons forged under the stress of emergency. Unfortunately, most of the gains came too late during the war itself to prevent an enormous amount of suffering and disablement.

Greatest offender of the insect-transmitted maladies was dysentery. This appears to have been the case in most major wars since those of Greeks and Egyptians before the Christian era. Easily second was the even more disabling malaria. The enemy, of course, suffered just as much. Malaria outbreaks were the major reason for German abandonment of both Corsica and Sardinia with hardly a shot fired, Colonel Cushing points out.

Much of the fight was carried on by entomologists at the Orlando, Fla., and Beltsville, Md., stations of the Department of Agriculture's Bureau of Entomology and Plant Quarantine. Effective insect repellents and killers were developed, but, since the problem had received little attention until the actual outbreak of war, some of these came too late to help. One difficulty was that new kinds of insect disease carriers, with which the researchers had no previous experience, constantly were appearing. It was only near the end of hostilities that the general fly, louse, and mosquito insecticide, DDT, could be supplied to troops in sufficient quantities.

That needs often were urgent is illustrated by Colonel Cushing with accounts of some little-known war incidents. For example, he quotes from a report:

> The men at the front in New Guinea were perhaps the most wretched looking soldiers ever to wear the American uniform. They were gaunt and thin, with deep black circles under their sunken eyes. . . . Many of them fought for days with fevers and didn't know it. . . . Malaria, dengue fever, and dysentery, and in a few cases typhus, hit man after man. There was hardly a soldier amongst the thousands who went into the jungle who did not come down with some kind of fever at least once.

Sand flies, with which American entomologists generally were unfamiliar before the war, might have cost victory in Sicily. "In the battle for Sicily," Colonel Cushing recounts, "31,158 soldiers were killed; *Phlebotomus* [the sand fly] put several thousand more out of action at a time when all available manpower was sorely needed for the invasion of Italy. From the Sicilian hills the sand flies welcomed the newcomers by pumping dose after dose of papatacci fever into their nonresistant bodies. Within a short week after the initial landing hundreds of men with the new and unfamiliar disease filled the hospitals. Unrecognized by the Army medical officers, many of these cases were considered to be simply relapses of malaria contracted in North Africa and entered on the hospital records as 'f.u.o.' (fever of unknown origin)."

ZOOLOGY.—*A new polychaetous annelid of the family Paraonidae from the North Atlantic.*[1]

MARIAN H. PETTIBONE, University of New Hampshire. (Communicated by Fenner A. Chace, Jr.)

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In working over some of the uncatalogued polychaete material in the United States National Museum, some specimens belonging to an undescribed species of Paraonidae were found. They were dredged by the *Albatross* in the North Atlantic in 1883 and 1884.

Family PARAONIDAE Cerruti
(Levinseniidae Mesnil and Caullery)
Genus **Aricidea** Webster, 1879

Type.—*Aricidea fragilis* Webster, 1879 (by monotypy).

Diagnosis.—Body long, slender, with numerous segments. Prostomium subconical, with dorsal median antenna and pair of nuchal organs. First or buccal segment achaetous, more or less fused with prostomium. Parapodia biramous, lacking distinct setal lobes, with simple smooth capillary setae, with conical to filiform postsetal notopodial lobes (sometimes referred to as dorsal cirri) and with or without postsetal neuropodial lobes (sometimes referred to as ventral cirri) on some anterior segments. Branchiae simple, paired, straplike, dorsal to notopodia, absent from few anterior segments (3–4) and from a long posterior region (9–60 pairs of branchiae). Anal cirri 3, filiform. Anterior end of digestive tube evaginable as a cylindrical or feebly lobed proboscis.

Subgenus **Aricidea** s. str.

Diagnosis.—With only capillary setae in notopodia, without modified acicular setae in some posterior segments. With or without modified setae (crotchets, acicular setae or setae with mucronate tips) in posterior neuropodia.

Aricidea (Aricidea) albatrossae, n. sp.
Fig. 1, a–f

? *Aricidea fragilis* McIntosh, 1885, p. 354, pl. 43, figs. 4, 5, pl. 22 A, fig. 18; not Webster, 1879.

The species is known from 14 specimens, all incomplete posteriorly, dredged in mud and ooze at four *Albatross* stations in the deep North Atlantic. The types (U.S.N.M. 28638, 28639) were taken at *Albatross* station 2018; May 7, 1883; 37° 12′ N., 74° 20′ W., 788 fathoms, blue mud.

Description.—Incomplete anterior end of 54 segments 15 mm long and 2 mm wide. Prebranchial region rounded, anterior branchial region strongly flattened dorsoventrally, more posterior branchial region and postbranchial region subcylindrical. Prostomium (Fig. 1, *a–c*) rounded anteriorly, wider posteriorly, with a short median antenna near middle extending back nearly to first setiger and with a pair of nuchal organs; no eyes visible. First or buccal segment achaetous, more or less fused with prostomium, enlarged anteroventrally and forming lateral lips of mouth; lobulated lower lip of mouth formed by ventral part of first two setigers. Branchiae consist of 26–30 pairs, beginning on setiger 4; they are simple and straplike, with short slender tips and they turn medially over dorsum from origins dorsal to notopodia (Fig. 1, a, e). Three prebranchial and anterior branchial segments (about first 20 setigers) with thick bundles of noto- and neurosetae which taper to fine capillary tips (Fig. 1, d, e). Notopodia and neuropodia of posterior branchial segments with setae becoming gradually fewer in number and more slender; postbranchial segments with small bundles of slender, capillary noto- and neurosetae (Fig. 1, *f*). Notopodial postsetal lobes on prebranchial segments conical (Fig. 1, *d*), on branchial segments subulate (Fig. 1, *e*), gradually becoming more slender and filiform (Fig. 1, *f*). Neuropodial postsetal lobe on first setiger conical (Fig. 1, *d*), nearly as large as notopodial; on about next 20 setigers low, rounded (Fig. 1, *e*); on rest of segments lacking. In all specimens examined, the posterior ends were lacking and the proboscises were not extended.

Remarks.—*Aricidea albatrossae*, a deep-water species, resembles the type species, *A. fragilis* Webster, found intertidally in Virginia and North Carolina (Webster, 1879, p. 255; Hartman, 1944, p. 315), and *A. belgicae* (Fauvel), reported from

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the Antarctic (Fauvel, 1936, p. 29; Monro, 1939, p. 127), in having a short prostomial antenna and in lacking modified neuropodial setae in the posterior segments (at least to setiger 54 in *A. albatrossae*); the three species differ as shown in the table opposite.

The anterior fragment (about 36 segments), reported by McIntosh (1885) as *A. fragilis*, from off New York in 1,340 fathoms may prove to be *A. albatrossae*.

	A. belgicae	*A. albatrossae*, n. sp.	*A. fragilis*
Number of pairs of branchiae	15–20	26–30	50–60
Neuropodial postsetal lobes	Absent	Conical on first setiger; low, rounded on about 20 setigers; absent on following.	Conical to low rounded on about 40 setigers; absent on following.

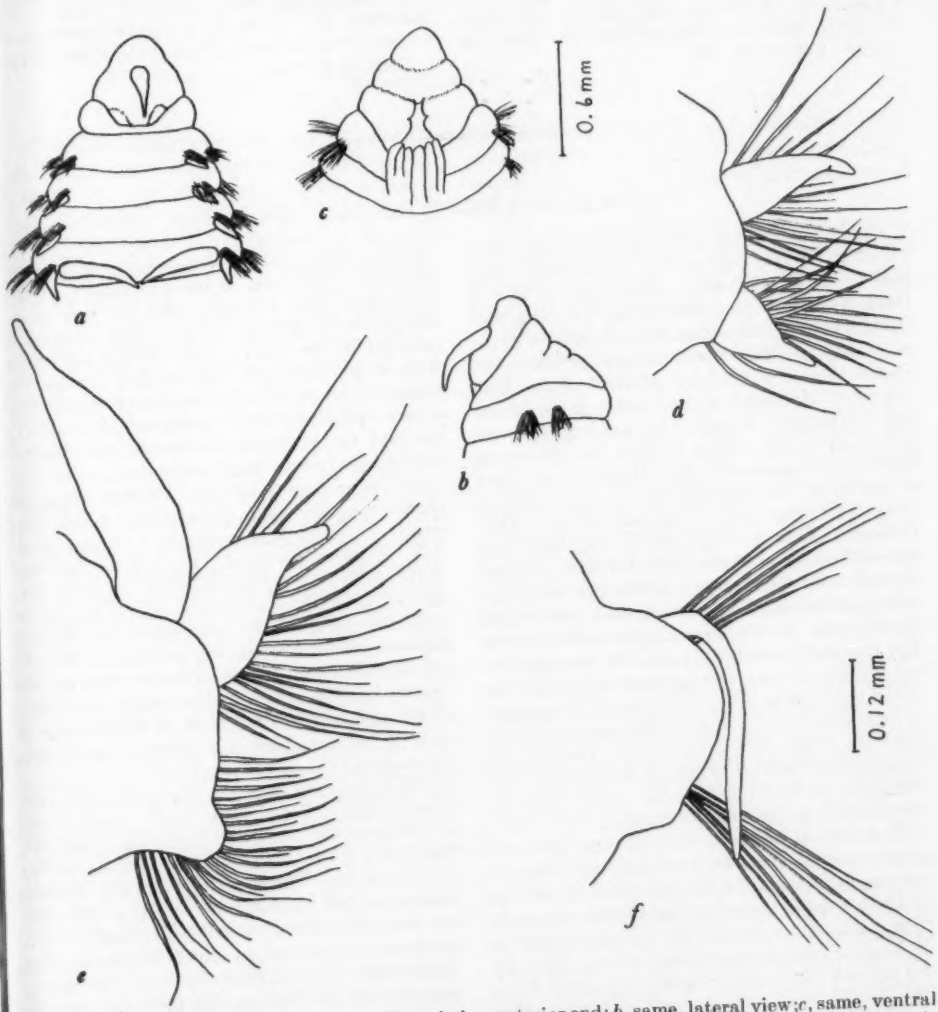

FIG. 1.—*Aricidea albatrossae*, n. sp.: *a*, Dorsal view anterior end; *b*, same, lateral view; *c*, same, ventral view; *d*, right parapodium from first setiger, posterior view; *e*, same, from setiger 7; *f*, same, from post-branchial segment. (All parapodia drawn to same scale.)

Additional records.—*Albatross* station 2072, 1883, 41° 53′ N., 65° 35′ W., 858 fathoms, gray mud; station 2105, 1883, 37° 50′ N., 73° 03′ W., 1,395 fathoms, globigerina ooze; station 2207, 1884, 39° 35′ N., 71° 31′ W., 1,061 fathoms, green mud.

Distribution.—Deep North Atlantic off Massachusetts to off Chesapeake Bay, 788 to 1,395 fathoms.

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FAUNAL CURIOSITIES OF CUBA

Lizards apparently immune to bullets, bat-crushing snakes, pigmy boa constrictors, frogs that never are pollywogs, and frogs less than a third of an inch long are among the curiosities of reptile and amphibian life recently collected in Cuba for the Smithsonian Institution by David Hardy, a graduate student of the University of Maryland. Most curious of the lot are the "bulletproof" lizards. They are large iguanas, 3 to 4 feet long, with a curious resemblance to antediluvian monsters. Mr. Hardy found them in limestone outcroppings and on sandy islands along the Cuban coast. When shot, he says, they turn over on their backs and lie still, but when approached the apparently dead reptile suddenly "comes to life again," gets on its feet with marvelous speed, and disappears down a hole. About the only way to collect specimens is with a noose. The supposed immunity to bullets, of course, is not quite true. Any creature can be killed if hit in the right place. Still, Hardy says, he captured one specimen with 22 shots in its body, apparently none the worse for the experience. The seeming immunity he believes is due to two things—the toughness of the hide and the quite primitive organization of the nervous system.

The bat-eating boas he collected are true members of the constrictor family and show a curious adaptation. In the Trinidad Mountains of Cuba's south coast are many bat caves. In their dark, damp depths literally thousands of fruit-eating bats spend the day asleep. They fly out at dusk. Each cave consists of several chambers, which have very narrow entrances, often barely big enough for a bat to squeeze through. The big snakes hide, coiled in rock crevices, beside these entrances. When the nightly exodus takes place a boa will strike time and time again, nearly always getting a bat, whose progress is impeded by the narrow aperture through which it must go. Then, after the fashion of boas, the animal is crushed in the coils and eaten. The snakes apparently have prodigious appetites. In one cave Hardy found 70 boas, and he obtained 9 dead bats from a single snake.

Another curiosity of Cuba's reptile life is the pigmy boa, less than 2 feet long, which lives mostly on small lizards, which it crushes in its coils. It progresses rapidly through the hot sand of its habitat by a "side-winding" type of locomotion, familiar in some rattlesnakes but otherwise unknown. Other boas have the sinuous motion common to snakes in general. In the side-winding movement, Mr. Hardy believes, the snake's body is momentarily almost completely off the ground with each twist. It may have been evolved, he speculates, as a means of relief from the searing heat of the sand.

The tadpoleless frogs are creatures of the rain-forest canopy, found only in the tops of the tallest trees and chiefly in high mountains. Mr. Hardy found one of the best collecting sites the summit of Pico Turquino in the Sierra Maestro Mountains, the highest peak in Cuba. The eggs, laid in pools formed in hollows of large leaves, hatch as frogs, not tadpoles, metamorphosis being completed entirely within the egg. The pigmy frogs are very rare but are distributed all over the island, often with gaps of 100 miles or more between colonies.